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SPACE PROGRAM BENEFITS

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

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HEARING BEFORE THE
COMMITTEE ON AERONAUTICAL
AND SPACE SCIENCES
UNITED STATES SENATE
NINETY-FIRST CONGRESS
SECOND SESSION
APRIL 6, 1970
WASHINGTON, D.C.

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Information concerning this material may be obtained from the Office of Technology Utilization , Office of University Affairs or Office of General Counsel respectively, National Aeronautics and Space Administration, Washington, D.C. 20546.

SPACE PROGRAM BENEFITS

MONDAY, APRIL 6, 1970

U.S. SENATE,
COMMITTEE ON AERONAUTICAL AND SPACE SCIENCES,
Washington, D.C.

The committee met, pursuant to call, at 10:05 a.m., in room 235, Old Senate Office Building, the Honorable Howard W. Cannon presiding.

Present: Senators Cannon, Young, Holland, Smith of Maine, Curtis, and Goldwater.

Also present: James J. Gehrig, staff director; Everard H. Smith, Jr., Dr. Glen P. Wilson, Craig Voorhees, and William Parker, professional staff members; Sam Bouchard, assistant chief clerk; Donald H. Brennan, research assistant; Mary Rita Robbins, and Carol L. Wilson, clerical assistants.

OPENING STATEMENT BY SENATOR CANNON

Senator CANNON. The committee will come to order.

Today the committee is meeting to hear testimony from Dr. Thomas O. Paine, the Administrator of the National Aeronautics and Space Administration. Dr. Paine will testify on the benefits that have accrued to our society from the space program. This is a matter of great interest to the Congress since the Federal Government allocates substantial resources to this program.

People in and out of the Government frequently ask the question: "What good is it doing?" It reminds me somewhat of stories told about the famous British scientist, Michael Faraday. Many years ago he was lecturing on one of his many discoveries when a member of the audience somewhat irreverently interrupted him, asking, "Yes, but what good is it?" Faraday's reply was, "What good is an infant?" On another occasion he was explaining to members of the British House of Lords the miracle of electricity and again was asked, "But what good is it?" Faraday's reply was, "Some day you will tax it."

Today we repeatedly hear the same question about the space program and it seems to me Faraday's replies then are appropriate now. The space program is only 12 years old and it is just an infant in terms of its development; nevertheless, some of the results from the space program have already produced goods and services which we tax.

So that this committee and the Senate and the public will have an assessment of just how robust an infant space is and can judge its potential for new wealth and revenue, the chairman of this committee, Senator Clinton P. Anderson of New Mexico, with the agreement of

other members, called this hearing today. Dr. Paine, Administrator of NASA, is here to give us a picture of how the space program is affecting our everyday lives and what NASA is doing to help get the fruits of the space program to those who can benefit from them.

Senator Smith?

Senator SMITH of Maine. I have no statement.

Senator CANNON. Very well.

You may proceed, Doctor.

(The biographical sketch of Dr. Paine follows:)

BIOGRAPHICAL DATA, THOMAS O. PAINE, ADMINISTRATOR, NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

(Appointed March 5, 1969; sworn in April 3, 1969)

Dr. Thomas O. Paine was born in Berkeley, Calif., November 9, 1921, son of Commodore and Mrs. George T. Paine, USN (Ret.). He attended public schools in various cities and was graduated from Brown University in 1942 with an A.B. degree in engineering.

In World War II he served as a submarine officer in the Pacific and the Japanese occupation. He qualified in submarines and as a Navy deep-sea diver and was awarded the commendation medal and submarine combat insignia with stars.

In 1946–49 Dr. Paine attended Stanford University, receiving an M.S. degree in 1947 and Ph. D. in 1949 in Physical Metallurgy. In 1946 he married Barbara Helen Taunton Pearse of Perth, Western Australia. They have four children: Marguerite Ada, George Thomas, Judith Janet and Frank Taunton.

Dr. Paine worked as a research associate at Stanford University from 1947 to 1949, where he made basic studies of high-temperature alloys and liquid metals in support of naval nuclear reactor programs. He joined the General Electric Research Laboratory in Schenectady, New York, in 1949 as research associate, where he initiated research programs on magnetic and composite materials. This work led to the first demonstration of the shape anisotropy effect in single-domain magnetic particles, and to the basic patents on "Lodex" permanent magnets. In 1951 he transferred to the Meter and Instrument Department, Lynn, Mass, as manager of materials development, and later as laboratory manager. Major projects ranged from development of photocells and non-arc-tracking organic insulation to solid-state nuclear reactor control systems and aircraft instrumentation. For the successful fine-particle magnet development program, Dr. Paine's laboratory received the 1956 Award for Outstanding Contribution to Industrial Science from the American Association for Advancement of Science.

From 1958 to 1962 Dr. Paine was research associate and manager of Engineering Applicatons at GE's Research and Development Center in Schenectady. This involved organizing and managing a new laboratory component engaged in technical-economic studies and development programs in lasers, medical, electronics, electric vehicles, and many other fields.

In 1963–68 he was manager of TEMPO, GE's Center for Advanced Studies in Santa Barbara, Calif. This 400-man, long-range planning and interdisciplinary study group conducted interdisciplinary research for federal, state and local governments, foreign nationals, banks, and industry. These programs ranged from criteria for selection of model cities to the logistics support system for Polaris submarines and from computerized management information systems to economic development in Africa. About 15 percent of these studies were for top management of the parent company.

On January 31, 1968, President Johnson appointed Dr. Paine Deputy Administrator of NASA. Upon the retirement of Mr. James E. Webb on October 8, 1968, President Johnson named Dr. Paine Acting Administrator of NASA. His nomination as Administrator was announced by President Nixon on March 5, 1969; this was confirmed by the Senate on March 20, 1969. He was sworn in by Vice President Agnew on April 3, 1969.

Dr. Paine's professional activities have included chairmanship of the 1962 Engineering Research Foundation—Engineers Joint Council Conference on Science and Technology for Less Developed Nations; secretary and editor of the E.J.C. Engineering Research Committee on the Nation's Engineering Research

Needs 1965–85; member, Advisory Committee and local chairman, Joint American Physical Society—Institute of Electrical and Electronic Engineers International Conference on Magnetism and Magnetic Materials; chairman, Special Task Force for U.S. Department of Housing and Urban Development; lecturer, U.S. Army War College and American Management Association; Advisory Board, AIME *Journal of Metals;* member, Basic Science Committee of IEEE and the Research Committee, Instrument Society of America; Collier Trophy Award Committee.

Dr. Paine is a member of the Sigma Xi; the Army and Navy Club, the Cosmos Club, the National Aviation Club, Washington, D.C.; New York Academy of Sciences; American Physical Society; Institute of Electrical and Electronic Engineers; American Institute of Mining, Metallurgical and Petroleum Engineers; American Society of Metals; Institute of Metals (London); Submarine Veterans of World War II; Society for the History of Technology; Marine Historical Association; American Museum of Electricity; Newcomen Society (London); Naval Historical Foundation; American Association for the Advancement of Science; National Association for the Advancement of Colored People; U.S. Naval Institute; Navy League; Association of the U.S. Army; Instrument Society of America; Associate Fellow, American Institute of Aeronautics and Astronautics; National Space Club Board of Governors; American Astronautical Society Fellow.

Dr. Paine received an Honorary Doctor of Science degree from Brown University on June 2, 1969.

STATEMENT OF DR. THOMAS O. PAINE, ADMINISTRATOR, NATIONAL AERONAUTICS AND SPACE ADMINISTRATION; ACCOMPANIED BY DR. GEORGE M. LOW, DEPUTY ADMINISTRATOR; WILLIS H. SHAPLEY, ASSOCIATE DEPUTY ADMINISTRATOR; ROBERT F. ALLNUTT, ASSISTANT ADMINISTRATOR FOR LEGISLATIVE AFFAIRS; DR. JOHN E. NAUGLE, ASSOCIATE ADMINISTRATOR FOR SPACE SCIENCE AND APPLICATIONS; AND LEONARD JAFFE, DEPUTY ASSOCIATE ADMINISTRATOR FOR SPACE SCIENCE AND APPLICATIONS

Dr. PAINE. Thank you, Mr. Chairman.

Mr. Chairman and members of the committee, early last Tuesday Explorer 1, America's first satellite, made a fiery reentry into the atmosphere over the South Pacific. Launched 12 years and 2 months before, this tiny 30.8-pound spacecraft discovered the earth's Van Allen radiation belts, and provided America's first reply to the challenge of Sputniks I and II. Next Saturday NASA plans to launch Apollo 13 with three astronauts and a 300,000-pound payload into earth orbit. If all goes well, Capt. Jim Lovell and his crew will then relight their Saturn V rocket's third stage for NASA's fifth lunar flight and third landing, during which they will conduct scientific experiments and explore the moon's ancient Fra Mauro formation.

America's first dozen years in space saw our orbital payloads increase from 30.8 pounds to 300,000 pounds—10,000 times—our speed record increase from 1,900 m.p.h. to 25,000 m.p.h.—13 times—and our flight altitude record increase from 126,000 feet to 234,500 miles—10,000 times

NASA astronauts have now logged a total of 5,843 hours in space, safely flying more than 70 million miles in the Mercury, Gemini, and Apollo programs. Twelve Americans have orbited the moon; four have left their footprints on the lunar surface. Between Explorer 1 and Apollo 13 NASA also successfully launched 154 unmanned space-

craft, 23 of them in cooperative international programs. These have returned new scientific and practical data of great value from observations of the earth, sun, moon, planets, stars, and the fields and particles of interplanetary space. Impressive practical benefits have been realized from experimental and operational weather, geodetic, navigation, comunication, and other global application satellite systems.

Although worldwide TV coverage of NASA missions has brought our dramatic space achievements before the largest television audiences in history, the benefits and full impact of our space program on society are just beginning to be understood. Our spectacular achievements in space have overshadowed the less dramatic but equally important story of the many benefits the Nation is realizing from our space program. I, therefore, particularly welcome this opportunity to appear before you this morning to discuss not only the scientific and technological benefits the Nation is receiving from NASA's work, but also the impressive values in many other fields which the average citizen is increasingly receiving as a dividend from the space program.

I shall outline, as I see it, the broad impact space is having, and will continue to have, on our society, our technology, our industrial economy, and our planetary environment. I shall touch upon the direct benefits to science, to meteorology, to communications and to management; and outline the new processes whereby NASA is more effectively transferring technical information and getting it used throughout our socioeconomic system.

BYPRODUCTS LISTED IN SEVEN APPENDIXES

We have brought with us several exhibits to illustrate for you some typical examples of the many valuable contributions space technology is making to nonspace problems. I shall mention a few of these byproducts in my testimony, but there are far too many to cover in the time available here today.

To give this committee a more complete picture, therefore seven appendixes are attached to my statement:

Appendix 1 describes the NASA technology utilization program, and includes 12 attachments listing reports, abstracts, conferences, computer programs, inventions and patents.

Appendix 2 describes NASA scientific and technical publications, of which more than 1.6 million were distributed last year. Representative recent titles are listed, and the distribution described, including the 3,211,500 microfiche [1] copies distributed on request in 1969.

Appendix 3 describes the space program's contribution to American schools, including audiovisual material and curriculum resources, of which the January 1970 issue of Social Education says, "* * * the curriculum publications of the National Aeronautics and Space Administration, NASA, are far ahead of anything educational publishers have produced." The Spacemobile project which in 1969 reached 3,306,410 students live and 20,391,500 via TV is also described and evaluated.

Appendix 4 describes each of the Space Research Laboratories built at 34 institutions of higher learning across the Nation during the

[1] Microfiche—A 4" by 6" sheet of microfilm on which are placed 60 individual pages.

1960's and in which more than a thousand young men and women have already done graduate work toward their doctorates.

Appendix 5 describes public interest in NASA, including in 1969 the 968,830 letters we received, the 37.6 million people who viewed our exhibits, the 9.8 million who saw NASA films directly, the 248 million who saw them on TV, the quarter of a million people who attended a talk by a NASA speaker, and the 2,600,000 visitors from all over the world who toured NASA's facilities.

Appendix 6 summarizes 1969 news media coverage of NASA's activities, including the 3,497 newsmen accredited to Apollo 11 from 57 countries, the 1,167,559 NASA photos distributed to the press, the 734 U.S. TV stations who subscribe to NASA's film features with an estimated 347 million viewers, and the 3,200 U.S. radio stations and 954 newspapers who subscribe to NASA features.

Appendix 7 describes the NASA reliability and quality assurance program, lists its publications, and provides examples of the Alert program which rapidly informs other agencies and industry of hazardous parts and materials of general concern, including the cause and recommended corrective action.

With your permission, Mr. Chairman, we will furnish this rather voluminous material for the record, and I will proceed to summarize the benefits of the space program to the Nation and to the average citizen.

1. IMPACT ON SOCIETY

Chairman Anderson recently observed the space advances of the past decade, culminating in the Apollo 11 lunar landing, were: "achievements that have moved the minds of men around the globe."

This is not hyperbole; it is an historic fact. Today we live in a different world because in 1958 America recognized the challenge of space and boldly made the required national investment to meet it. Since then over a billion children have been born all around the world, the first space age generation.

Because of the space program, they will learn a new science, a new cosmology, and a new view of man and his destiny in the universe. Our dramatic flights to the moon rightly appear to us as a revolutionary victory of mankind over the earth's gravity and the vacuum of space, which previously confined life to our home planet earth, but they will be commonplace to this generation.

Today's children can look ahead confidently to new opportunities and to great new strides that man will make in the 21st century, when they will be in their thirties and forties. Their generation will view the earth as a whole for the first time, and be able to deal with technology, with science, and with philosophy as a unified experience, common to all men of the blue planet earth. This will have profound consequences, which we can just begin to perceive. But we, of course, can no more fully visualize the effect of this new technology on their lives 30 years hence, than we could fully visualize today's technology back in 1940.

I do not know how to express in dollars the human values of new horizons and of new hopes for a better world that have resulted from the space program's demonstration that free men of competence and good will can work together within our institutions to achieve almost impossible goals. And I believe the space program will continue to act

as a spur to other parts of our society, providing a needed challenge and a yardstick by which to measure human achievements in other areas.

NASA has shown how to create a uniquely American blend of governmental, industrial, and academic research competence and achievement. Without changing our system, we have learned how to forge these dynamic elements together in new ways, creating an effective team which released and directed the creative talents and energies of the American people.

Of course, some have grumbled that we are doing too much in space, with so many unsolved problems here on earth. But the positive approach is not to do less in space but to do more on earth—and do it better. We must continue space progress while at the same time applying the lessons we have learned from our space achievements to other U.S. needs. If this Nation can go to the moon, it can, and indeed must, do far better in meeting our other challenges. America's space achievements surely increase, not decrease, our hope, our ability, and our national resolve to face and overcome new and chronic earth problems.

Our history as a democracy shows that two principal stimuli have generated periods of vigorous American scientific and technological advance: the open frontier of an empty hinterland, and the challenge of a major war.

For generations the American frontier drew our expanding population westward, and stimulated advances in sailing ships and steamboats, canals and railroads, agriculture and farm machinery, electric power and telephony, highways and autos, radio and television, and transcontinental pipelines and airlines. New technologies provided the needed new communications and new mobility for people and freight on a continental scale.

In addition, the Civil War and two World Wars accelerated U.S. industrial development in the heavy metallurgical industry, shipping, chemicals, aviation, electronics, synthetic materials, pharmaceuticals, nuclear power, and other areas. Now, the space age is adding an effective new stimulus. During the 1960's without a new land frontier and without the anguish of global war, the American space program combined the forcing functions of both—and did it with noble motivation: exploration of the unknown, the expansion of knowledge, unselfish sharing of the new for the betterment of all, and reduction of international tension.

The endless physical, psychological, technical and scientific frontiers of space have stimulated development of entirely new transportation, communication and management systems: manned and automated spacecraft, launch vehicles, cryogenics,[2] tracking systems, computer networks, data links, ground support facilities, and new global institutions to manage them. International competition in space has given us and the world a better view of American and Soviet institutions and their capabilities. Without the horrors of war, space competition has stimulated advances in both nations in science and the applications of new science and technology.

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[2] Cryogenics—The branch of physics that deals with very low temperatures.

SOVIETS EXAMINE BENEFITS

It is interesting that Soviet leaders are also examining the benefits they are receiving from their space program, and finding them substantial. The March 15, 1970, issue of "Socialist Industry" devoted a full page to a dramatically headlined and illustrated article entitled, "The Cosmos Serves Man."

One of the Soviet Union's most distinguished scientific statesmen, Academician M. V. Keldysh, president of the Soviet Academy, described in glowing terms the benefits astronomy is deriving from cosmonautics, which allows observation at wave lengths absorbed by the earth's atmosphere. He stated that this "* * * promises us much information on the structure of the universe."

Other writers stressed other returns from their space program. Forecasted future benefits included a proposed nationwide newspaper printing system based on satellites. The writer predicted that "the time will come when central newspapers will be printed in Siberia, the Far North, and in the Far East, not from matrixes sent from Moscow by airplane * * * but from impressions of newspaper reprints transmitted over special channels" and that "the new rapid apparatus will assure 'the transmission' of a newspaper column to the place of printing within several minutes along the channel; Moscow printing house to transmitting station to satellite to receiving station 'Orbit' to the local printing house."

Thus the Soviets view their benefits from space in terms similar to our own, and see a promising future as we do. The Russian exhibit at the Osaka World Fair is heavily oriented toward space, indicating their pride in past accomplishment and resolve to move forward in the future.

SPACE STABILIZING FORCE IN WORLD AFFAIRS

Space has certainly given both America and the Soviet Union a unique opportunity to demonstrate before the entire world their national will, the strength of their institutions, the quality of their people, and the vision of their leaders. It has, in my opinion, been a major stabilizing force in world affairs by supplying an alternative to military confrontation for demonstrating to the world relative national power without upsetting the delicate balance of international security. And continuing U.S. progress in space will, in my opinion, constitute a stabilizing force in the world—a program which inspires international respect and cooperation.

On this point, we have a statement from the Department of State. I should like to read a few excerpts from this statement and with your permission submit the complete text for the record. The first excerpt is as follows:

> The unprecedented success of the program, the free and unfettered openness with which it has been conducted, its contributions to science and to commerce, and the technical and diplomatic skills of our astronauts have all added greatly to the prestige of the United States in the eyes of the world and to our influence in world affairs.
>
> The strength of a nation can be defined very narrowly in terms of its ability to fend off enemy action, or it can be defined more broadly and meaningfully as a function not only of the nation's security but also of a variety of essential components ranging from productive, technical and managerial capacities to

the health, education, motivation and sense of unity of the people. Using either of these definitions, the contributions of the space program to America's strength are too large and too obvious to need specification in this statement.

The second excerpt I would like to read is:

In summary, the success and character of the space program have had an important and highly beneficial effect on our posture in the world and our foreign relations. It has added to our national strength in many ways, and promoted national security. It has provided a medium for significant enhancement of the partnership we seek with friendly nations and for the successful negotiation of agreements with the Soviet Union. * * *

Senator CANNON. Do you desire to have the complete statement made a part of the record?

Dr. PAINE. With your permission, yes.

Senator CANNON. It will be made a part of the record.

(The statement referred to above follows:)

DEPARTMENT OF STATE,
Washington, D.C., April 3, 1970.

The Honorable THOMAS O. PAINE,
Administrator, National Aeronautics and Space Administration.

DEAR DR. PAINE: As you know, the Department of State attaches great importance to the contribution which the space program makes to our international posture and to the conduct of our foreign affairs. We are pleased to enclose a statement evaluating this contribution which you may wish to make available to the Senate Aeronautical and Space Sciences Committee.

Sincerely,

U. ALEXIS JOHNSON.

EFFECT OF THE SPACE PROGRAM ON AMERICA'S FOREIGN RELATIONS

In his February 18 report to Congress on "U.S. Foreign Policy for the 1970's", The President identified three central principles on which American foreign policy will be based: partnership among friends and allies, strength, and the willingness to negotiate with the Communist nations. Frequently and substantially, these three pillars of foreign policy are being augmented by various aspects of America's space program.

The unprecedented success of the program, the free and unfettered openness with which it has been conducted, its contributions to science and to commerce, and the technical and diplomatic skills of our astronauts have all added greatly to the prestige of the United States in the eyes of the world and to our influence in world affairs.

The strength of a nation can be defined very narrowly in terms of its ability to fend off enemy action, or it can be defined more broadly and meaningfully as a function not only of the nation's security but also of a variety of essential components ranging from productive, technical and managerial capacities to the health, education, motivation and sense of unity of the people. Using either of these definitions, the contributions of the space program to America's strength are too large and too obvious to need specification in this statement.

In less than a decade since the launching of the first applications satellites, we are also reaping major practical benefits through greatly improved worldwide communications and navigation systems and through increasingly comprehensive and precise understanding of the dynamic processes of the atmosphere which in turn leads to better weather forecasting and to the expectation that the fury of major storms can soon be tamed.

The search for partnership with friends and allies has, of course, been a goal of open societies and enlightened nations throughout history. In earlier times this search largely followed commercial, military and diplomatic channels. These classical channels continue, of course, to be of great importance, and they have been reinforced in recent years by the possibilities of strengthening the concept of partnership through joint efforts toward common objectives in science and technology. Many aspects of the space program are inherently global in character, and the challenge and excitement of exploring and finding practical uses for outer space have provided a rich field for such joint enterprises where the United States and many of the nations of the free world have been able to

share in the work and in the rewards. Several of the leading nations have built scientific satellites which have been launched into orbit with our rockets; scientists of twenty nations have designed and constructed experiments which have been incorporated in our satellites and sounding rockets; and dozens of foreign geologists, minerologists, chemists and physicists, working in their own laboratories in sixteen nations, are now contributing their skill to the fascinating task of unravelling the scientific mysteries of the lunar rock and soil specimens brought back from our Apollo missions.

In the field of space applications, joint efforts with many of our friends and allies have made it possible for all to reap great gains from communications satellites and meteorological satellites, and thought is being given to cooperative arrangements which will put to good use the information which will be derived from the earth-resource satellites scheduled for launch during the next few years. As we move into the post-Apollo era of space activities and face the challenge of such projects as the space shuttle, the manned space station and the Mars landing, there is every reason to be confident that the concept of partnership with our friends and allies will continue to gain strength as we share the responsibilities and rewards of these ventures.

America's willingness to share this adventure in science with other nations reflects the open character historically associated with our nation. This openness has also guided our space program's public information policy. Fully aware of the risks involved, we have nevertheless encouraged the world to watch on live television the most dramatic and dangerous moments. Many hundreds of millions of people throughout most of the world watched and felt deep personal involvement in the moonwalk. The massive and emotional response on that memorable July day was unprecedented in history. The excellent impression created by the Apollo astronauts during their subsequent visits to many nations and the displays of moon rocks in nearly 70 countries have generated a warm response and have helped greatly in deepening the sense of personal participation of the peoples of the world in our space program. The euphoric burst of enthusiasm felt by most of the world toward our country last July has, of course, subsided, but we are left with residue of admiration and prestige not only for the event itself but for the open way in which we invited the world to share in the adventure. This should continue to be of very real value with respect to our posture in the world and our relations abroad for many years to come.

No aspect of our diplomatic effort world-wide is more important than what the President described as "patient and precise efforts to reconcile conflicting interests on concrete issues" between ourselves and the Communist nations. In the field of space activities, as in other areas, the progress of such negotiations has frequently been disappointingly slow. Even so, the effort has been far from fruitless. Working through the framework of the United Nations, we have joined the Soviets and many other nations in a Treaty on Outer Space which, among other things, states that no nation can claim sovereignty to outer space, to the moon or other celestial bodies, and forbids the stationing of nuclear weapons on celestial bodies or in space.

A still more recent Agreement on Rescue and Return of Astronauts has been completed, and we are now working toward an international understanding on liability for damages caused by space activities.

The use of space for various peaceful purposes of proven and predictable benefits to mankind has already forced the nations of the world to the development of new modes and concepts for the management and use of global technologies. INTELSAT and the World Weather Watch are presently the outstanding examples of this. Historians of the future, looking back upon this era, may not only marvel at the speed with which mankind conquered space and put it to his use but, hopefully, will also marvel at the ingenuity and wisdom displayed by mankind when forced to develop international innovations necessary to assure the productive and peaceful exploitation of the potentials of space.

In summary, the success and character of the space program have had an important and highly beneficial effect on our posture in the world and our foreign relations. It has added to our national strength in many ways, and promoted national security. It has provided a medium for significant enhancement of the partnership we seek with friendly nations and for the successful negotiation of agreements with the Soviet Union. Only twenty years ago the space program was a gleam in the eyes of a few men then regarded as visionaries; today it influences the lives of a considerable fraction of mankind, and stands in the vanguard of the new and rapidly accelerating global technologies.

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Dr. PAINE. Space has made the world seem smaller, more fragile and precious, and at the same time made man seem larger. Our view of the entire globe from space inspired Archibald MacLeish "to see the earth as it truly is, small and blue and beautiful in that eternal silence where it floats."

I am sure this has provided a new stimulus for man to look harder at his environment here, and to resolve to decrease pollution by managing the life support systems of "spacecraft earth" as carefully as we do those of Apollo, tempering our appetites for the present with an increased regard for our future.

2. IMPACT ON TECHNOLOGY

The most direct and easily grasped returns from the space program are, of course, the great technological advances in the form of new aerospace equipment which can carry man and his automated probes faster, farther, higher, and more reliably around the earth, and outward into new regions of the solar system and beyond. This has required the development of new systems that work effectively under conditions once deemed prohibitive. Behind this are many technological advances in the form of new materials with properties before deemed impossible to achieve, new processes and techniques that work faster, more reliably, and with greater precision, and greatly advanced computer, communications, and data-handling capabilities.

I am convinced that the current level of U.S. technology would be substantially lower without the advances that NASA required in every technical discipline in order to get to the moon. Furthermore, the knowledge we gained is not transient but permanent. Once you know how to do something that knowledge is reapplied over and over again, in as many fields as there are engineers. In turn, it leads to other advances in related technologies, not only by the innovator but by his competitors. This is not "spinoff"; it is the complex process of steady hand-over-hand technological progress.

COMPUTER INDUSTRY

An excellent example of space-stimulated technical progress is the impact of new space requirements on the computer industry. The exploration of space demands very large computer systems of great complexity, size, and speed. More importantly, space needs demand new flexibility in the use of computers, ranging from automated checkout functions to realtime monitoring of space missions, from inventory management to aircraft and spacecraft simulator controls, from computing planetary trajectories to modeling global weather patterns.

NASA has to receive advanced hardware meeting rigid specifications on schedule, to meet unyielding planetary launch window dates. We need new kinds of computer programs—and we know that complex software programs require leadtimes as long as the hardware. NASA does get advanced computer hardware and software on schedule; without them, Mariner, OAO, Apollo, and other missions would not have flown successfully.

The need for rapid progress has been relentless. In Project Mer-

cury, ground-based computers were only required to determine, quickly and accurately, booster cutoff conditions. In Apollo, however, computers are used throughout the mission in real time, to calculate the trajectory to the moon and back, to compare three separate solutions for the lunar descent, to record and analyze thousands of bits of telemetered spacecraft information, to compare these to predicted values to detect trouble, and at the same time to monitor the well-being of the crew.

For Mercury, the computer program contained 40,000 "computer words"; for Apollo, a 1,500,000-word program was needed.

Challenging the best talents of our Nation in this way—to produce both hardware and the programing that makes it useful—has helped the U.S. computer industry to attain its present dominant world position. The industry engineers who developed our Mission Control Center computer system at Houston for Apollo tell us that without the forcing functions of NASA's requirements, they would not have been able to exploit fully the inherent capabilities of their own machines to meet other requirements. Virtually every on-line, direct-access commercial computer system in the world today is American, and reflects the space guidance and checkout requirements of some years ago.

The U.S. computer industry does about $8 billion worth of business a year. It pays the highest average wages of any U.S. industry, is one of the most rapidly growing, and contributes a large positive international balance of trade. You might be interested in reviewing a few statistics here. In 1960, the U.S. exported $48 million worth of computers; by 1965, this had risen to $223 million, and it reached $728 million in 1969. U.S. computer exports have increased over 1,400 percent in the first decade of the space age, and prospects for this decade are equally bright if progress continues.

This impressive record is built on excellence of performance through continuing technological superiority. The economic health and growth of this vital new segment of U.S. industry is creating significant national capital, now and for years to come. NASA is proud of the degree to which our stimulus and support of technological advance has encouraged and assisted the computer industry's growth.

Not only did we get full value in the direct results that the Government paid for, but the entire Nation is benefiting from the economic and technological contributions of this industry. America's investment in the computer industry in the 1960's may well prove to be the most beneficial technoeconomic decision for the second half of the 20th century.

AVIATION INDUSTRY

Continuing technological progress is necessary to maintain leadership in every field; history proves there can be no resting on the oars. Although the Wright brothers invented the airplane, there was little subsequent support in America. As a result, during World War I American pilots flew only French and British planes; there was no ready U.S. aviation industry.

In the Second World War, the Me 262 jet fighter was operational while America was still testing prototypes. The British flew the first

jet transport; the first supersonic transports will be the Anglo-French Concorde and the Russian Tu 144. International competition in aviation is intensifying. More than national commercial interest is at stake in a strong aerospace industry; it is today a matter of national survival.

U.S. leadership in aerospace technology continues to mean much to the Nation in many ways, including national defense. For example, the helicopter is revolutionizing Army tactics and logistics, vastly increasing the mobility and power of our ground forces. Similarly, today's Navy and Air Force show little resemblance to their counterparts of 20 years ago; missile developments have completely changed our strategic concepts. Aerospace leadership can be expected to remain a prime requisite for future national security.

What U.S. aerospace leadership means to the Nation in civil fields is evident at airports around the world, where American aircraft are seen bearing insignia of almost every national airline.

All American aircraft flying today, civil and military, reflect technical contributions by the NACA. Continuing NASA research in aerodynamics and engines, materials and structures guidance and controls, coupled with flight tests and wind tunnel experience, are supporting the aerospace industry, the airlines and their passengers.

Aviation is no longer an alternative form of transportation; it has become the backbone of national and international passenger traffic. In 1964, there were 83 million U.S. airline passengers; in 1969, there were 168 million—a doubling of passenger traffic in only 5 years. In 1964, we had 432 commercial jet transports; in 1969, there were 1,781—a fourfold growth. At the same time very high safety standards have been achieved.

AEROSPACE INDUSTRY

The importance of aerospace to the United States can be put into another perspective: It is now America's largest manufacturing industry, employing 1.3 million people with a $14 billion annual payroll. This industry does an annual business of $27 billion—and last year had a $28 billion backlog. U.S. exports of aircraft and parts climbed from $1.1 billion in 1964 to $2.9 billion in 1969. The aerospace industry is thus one of our great producers of national wealth. America would not have this vital industrial capacity, competence, and output today had we not made continuing technological investments in the past. This will hold true even more so in the economic equations of the future.

THE RESEARCH AND DEVELOPMENT PROCESS

An excellent example of NASA work on a problem of concern to people everywhere is our program to reduce jet engine noise. Present engines, derived from military predecessors, are major offenders in urban areas today. Working with Boeing and McDonnell-Douglas, NASA had recently demonstrated an economically feasible approach to alleviating the worst part of this noise. An acoustic muffling treatment for 707 or DC–8 engines has been demonstrated that can reduce by 85 percent the area around an airport subject to severe noise—100 effective perceived noise decibels.

The longer term solution—an engine designed from the inside out to be quiet—is also underway in NASA's aeronautics program. What is significant here is not just the solution itself—as desirable as that is—but the way in which it is being achieved. The people who are doing this work, who understand the theory, technology and problems, are members of the unique NASA Government-industry-university team, working together under NASA on this difficult task. So once a concept like acoustic nacelle treatment is proven, Federal airport regulations can be made to require it, and U.S. industry will have already proven its ability to respond practically to the regulation. Not a "spin-off," this is the kind of direct practical benefit the average citizen is getting from our program.

Many other examples can be cited from the past, like NASA's "area rule" which resulted in the "coke bottle" shape of all modern high performance aircraft, or the variable sweep wing, or titanium alloys, or ground simulators, or inertial navigation systems, or grooved runways. The main point here, I believe, is not that research per se is valuable; that is seldom disputed today. It is that the effective way in which research and technical development is organized and managed by NASA is acting as a powerful multiplier on its value, getting practical R. & D. results into the minds and hands of people who can use it because it meets their requirements and objectives.

Technology transfer is very effective within corporations. The Boeing Co. that met the stiff requirements of the Saturn S–IC rocket stage is now manufacturing the 747 jumbo jet; the inertial guidance system on the 747 is made by AC–Electronics Division of General Motors, which made the guidance system for Apollo; the McDonnell-Douglas Co., which developed the Mercury spacecraft and the Saturn S–IVB stage, is now building the DC–9 and DC–10.

Many people who have worked on NASA programs have now taken their knowledge and skills into other aerospace fields. The aerospace industry has, as an inherent part of its operations, always stressed personal mobility and interdisciplinary learning. New programs are organized as old ones phase out, bringing the experience and advances of the past directly to bear on the future. This flexibility is a powerful force for progress, diffusing new technology both within companies and throughout the national economy.

This diffusion is not, of course, limited to aerospace activities. Let me cite one example from the automotive industry. In order to meet new Clean Air Act criteria, the Chrysler Corp. reworked their automobile ignition systems, designing distributors to operate within much closer limits. To assist in this they called on their own personnel who had developed the automated checkout and launch sequence equipment for the Saturn launch vehicle. At Chrysler's Indianapolis plant today, every distributor is dynamically tested for final acceptance throughout its entire range on computer controlled equipment derived directly from Apollo program checkout equipment. The system works so well that they are using the same computer system to check out windshield wiper motors, and are now applying the same approach to small sack and parcel sorting equipment for the U.S. Post Office.

This is the complex network process of technological transfer and growth. The inputs are varied, including many from space challenges

and discoveries; the outputs are national productivity, wealth, and power. To the man in the street, this means more and better jobs at higher wages, and better and cheaper products.

This is a difficult process to understand and explain to the public, however. Clearer and more direct benefits are apparent to everyone from NASA's science programs and applications programs, which I will now discuss briefly.

3. SCIENCE PROGRAM

NASA's investments in space science have provided returns in two classes: scientific returns in themselves, and resulting practical benefits. The new perspectives afforded by our newly acquired ability to study directly the moon and other planets is illuminating the study of our own earth.

Our ability to probe into the origin of the earth and the solar system has been limited by the fact that the earth's crust appears to be about 3.5 billion years old, or about 1 billion years younger than what is thought to be the true age of the solar system. Moreover, the record of earth's history is constantly being erased by erosion, folding, cracking, and other movements in the earth's crust. Many pieces to the puzzle of how the earth and planets were formed will necessarily be missing if we are constrained to examine the earth alone.

The moon in particular has long been thought by scientists to be a potential Rosetta stone for interpreting the history of the solar system. Since the surface of the moon has been spared most of the processes of change that occur on earth, the moon's surface has apparently preserved the record of its long history since the formation of the solar system 4.5 billion years ago.

The discovery from Apollo 11 and 12 that much of the lunar soil is indeed 4.5 billion years old was a most profound result, and our continuing investigation of the moon promises to be very productive in understanding not only the moon but also our own planet.

SPACE ASTRONOMY

Space astronomy has come into being at an exciting time when astronomers are wrestling with some of the most puzzling problems ever turned up in man's investigation of the universe. Huge radio galaxies, quasars, pulsars, and numerous X-ray sources are still unexplained. Some of these objects emit energies at unbelievably prodigious rates, suggesting that we may be witnessing new, powerful modes of energy production, different from those we have known in the past.

Recalling that our present-day knowledge of nuclear energy stemmed from inquiries into how the sun produced its radiant energy, we can speculate that today's space astronomy may eventually also yield results of tremendous practical importance. Satellites provide the means for making observations in the radio, infrared, ultraviolet, X-ray, and Gamma-ray wavelengths that cannot penetrate the earth's atmosphere to the ground, so space astronomy is giving astronomers powerful new tools for investigating these challenging questions.

SPACE PHOTOGRAPHY

Space photography enables us to view the entire earth in a new perspective not obtainable from aircraft or balloons, permitting us to study the earth and its atmosphere in detail, to search for new resources, to monitor water resources, agricultural activity, and forest stands, to explore the oceans, and to assist in large-scale civil engineering.

SPACE GEODESY

Space geodesy has taught us the true shape of our planet, where it flattens, how much it bulges. With these results we are better able to map the earth and navigate. Space observations enable us to calculate accurately the earth's gravitational field, knowledge of which is important to the operation of space vehicles and satellites for exploration, science, and applications.

We know now that the atmosphere of the earth has an upper boundary, that it does not extend indefinitely out into space, as previously believed. We know also that the earth's magnetic field in space is not like that of a simple bar magnet extending indefinitely outward, but is instead very complicated.

The discovery of the Van Allen Belt of trapped radiation, of the magnetosphere within which the Van Allen Belt lies, and the solar wind, together have revolutionized all earlier concepts of space around the earth. This new picture of the earth's upper atmosphere and the properties of near earth space are important in helping to understand how the sun's various radiations literally control our atmosphere, including our weather and climate.

The study of our sister planets is directly contributing to our investigation of the earth itself. As Dr. Gordon MacDonald points out, studies of the Mars atmosphere have highlighted the importance of radiative transfer of energy in atmospheric dynamics, giving us an insight into our own atmosphere that we are able to achieve only through the perspective afforded by looking at another planet.

Dr. Eshelman has found that planetary atmospheres are quite fragile. He points to the tremendous changes that earth life has caused in the earth's atmosphere in eons past, and emphasizing that the study of planetary atmospheres may be our most powerful way of discerning the true nature of the changes on earth that we ourselves are now causing.

POSSIBLE CHEMICAL CONTROL OF CANCER

Not all of the benefits of space science come from observations in space. Many of the beneficial results stem from associated or preparatory work done in the laboratory. The work of Mr. C. B. Cone, Jr., at Langley's Molecular Biophysics Laboratory is an excellent example. Mr. Cone was studying radiation effects on cells in order to understand possible space radiation effects on astronauts.

In the course of his work, he discovered that the electrical voltage across the surface membrane of a normal cell acts to exert precise control over cell division. This implies that it is an alteration in the molecular structure of the cell surface that permits the uncontrolled

proliferation and metastasis[3] characterizing cancer. This wholly new theory, verified in preliminary tests, has opened a promising new avenue for possible chemical control of cancer.

Another example from NASA's biological research highlights the interactions of science and technology and how hard it is to separate the components of science and engineering. Dr. Fernandez-Moran at the University of Chicago was working on cell structure for NASA, but his requirements carried him beyond the range of commercially available electron microscopes.

His resulting improvements produced the world's most powerful instrument of this class, capable of magnifying objects 20 million times and resolving images down to two angstroms.[4] To handle the electric power necessary to operate the microscope without melting required another breakthrough to cool the magnetic lens of the microscope: the first large-scale continuous closed-cycle production of superfluid helium.

In order to use the full magnifying power of the microscope, it was necessary to prepare specimens to the same scale. The diamond knife invented by Dr. Fernandez-Moran to solve this problem can dissect away portions of a molecule or cut a hair into 10,000 length-wise strips. In order to record images from the electron microscope, a film virtually without grain was required—and invented. It works instantaneousy and can be converted readily into color images by interference microscopy. These developments resulting from this one scientific investigation illustrate the many benefits in various fields which work in space science is stimulating.

The intellectual understanding of the universe around us is at the heart of man's ultimate superiority over undiscerning animal instinct. The pursuit of this intellectual understanding is one of the greatest of human adventures.

The space program has probably done more to interest young people and the average citizen in science than any other activity. The thoughtful laymen is impressed and appreciates the opportunity to share the excitement of discovery which NASA has provided. This result alone is of very substantial value to the Nation and to science.

I will now move on to describe the impact of the space program on three specific fields: meteorology, communications, and management.

4. IMPACT ON METEOROLOGY

It is rare for a new field of technology to produce practical applications in its first few years, but this happened in the early 1960's when the space program developed and put into operation revolutionary new tools and information systems for weather forecasting. These included:

Sounding rockets to take vertical profiles of the atmosphere from surface to space;

Satellites to provide a continuous watch of the earth's moving cloud cover;

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[3] Metastasis—The transfer of disease from one part of the body to another not directly connected with it, with development of the characteristic lesion in the new location.

[4] Angstrom (after Anders J. Angstrom, Swedish physicist).—A unit of length equal to one ten-thousandth of a micron or one hundred-millionth of a centimeter, used in expressing the length of light waves.

Solar observation satellites to monitor the sun's cycle of activities;

Satellites to track storms, measure winds, record the temperature at different heights, and report on the moisture content of the atmosphere;

Ground and airborne radar and lasers to probe weather conditions from below;

Computer systems, mathematical models and software programs that can receive and analyze vast amounts of global data from many sources to make possible more accurate forecasting; and

Data transmission systems to link together the various parts into one global meteorological network.

VALUE OF SPACE WEATHER FORECASTING

Progress in weather satellites continues to be rapid. Since April of last year, a new infrared spectrometer [5] on Nimbus III has been measuring the vertical temperature of the atmosphere. It has proven highly accurate, providing every day electronically from orbit the equivalent of 10,000 conventional atmospheric soundings by balloon or sounding rocket. The first use of this capability in operational forecasting began last June, and has resulted in significant improvements in predicting features of upper atmospheric flow.

Important as it is, forecasting is only one part of the weather picture that impacts our daily lives. Probably the most dramatic impact of weather satellites is their ability to detect and track major storms, hurricanes, and threatening weather patterns early enough and precisely enough to permit timely warning and decision. Examples include routing of air traffic, marine navigation, agricultural warnings, water management, and the protection or evacuation of threatened flood and storm areas.

50,000 LIVES MAY HAVE BEEN LOST IN HURRICANE CAMILLE WITHOUT WEATHER SATELLITE

Camille was first observed and then tracked by satellite. The hurricane's path, force, and extent were predicted early and accurately enough to permit authorities to evacuate some 70,000 people from the gulf coast. Without early warning, without tracking, without the credibility provided by actual satellite pictures and data, ESSA estimates that 50,000 people might have perished in this devastating storm. This is not an isolated case; many other instances can be cited.

HURRICANE LAURIE

In November of 1969, Hurricane Laurie also threatened the gulf coast. Observation and tracking by satellite provided the basis for safely predicting that Laurie would not strike the coast. The savings here from the decision not to evacuate and not to protect property are estimated to have exceeded $3 million.

This kind of benefit is not confined to the United States. In late 1968, heavy rains threatened to overload a reservoir in Mexico's Nazas

[5] Infra-red spectrometer—Instrument fitted for measurements in the infra-red portion of the spectrum.

River valley and break the earthen dam. Releasing the water to relieve the pressure would have inundated two towns—Torreon and Gomez Palacios—and produced a critical shortage of irrigation water later. On the basis of satellite pictures showing clearing weather, ministry officials made the decision to keep the dam closed. The rains indeed stopped, the dam held, saving both the water supply and the towns.

WATCH EVERY MAJOR STORM

These are but a few examples; since 1966 U.S. weather satellites have watched every major storm threatening the Nation. In 1969 alone, 12 Atlantic hurricanes, 10 eastern Pacific hurricanes, and 17 western Pacific typhoons were identified and tracked by satellites. We now have the first atlas of Pacific cloud and weather patterns, covering the period 1962 to 1969, assembled from data available only by satellite.

Color TV cloud pictures from NASA's experimental Applications Technology Satellite (ATS) in geostationary orbit[6] are now being used in near-real time. The Navy uses weather satellite pictures for ice patrols and to schedule Antarctic resupply. Airline pilots at Kennedy Airport routinely receive a weather photo of their transatlantic route.

FIFTY COUNTRIES USE WEATHER SATELLITES

One final point: satellites and weather are inherently global systems. By using automatic readout systems, every nation in the world can benefit from the automatic picture taking (APT) systems onboard U.S. weather satellites. Over 50 countries are now using this to view daily weather patterns over their own territory—a wonderful example of the use of space for the benefit of men everywhere.

These same countries also benefit from cloud picture mosaics routinely made available by the weather bureau to Europe, Asia, Australia, and North and South America. The weather mosaic is built up from individual weather photos and processed by computer; it is then retransmitted from the ESSA ground station via NASA satellites. This is a very real example of the combined benefits—national and international—that space systems are creating for the average citizen.

5. IMPACT ON COMMUNICATIONS

Before discussing communication satellites, let me cite a few telecommunications statistics to put this important development into perspective. In 1960, there were less than 75 million phones in America; we now have about 120 million. In 1960, Americans made 18 billion phone calls; last year we made nearly 200 billion. Before the end of this day about 485 million phone calls will have been made in this country.

The value of the U.S. telecommunications business, including service equipment, grew from $22 billion per year in 1960 to over $47 billion now. This industry has doubled its circuit mileage every 10 years since 1935.

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[6] Geostationary orbit—The orbit of a spacecraft (at 22,300 miles altitude) where the angular rotation of the craft matches the angular rotation of the earth. In this situation the craft appears to remain stationary over one point on earth. (Also called geosynchronous orbit.)

NEW USES FOR TELECOMMUNICATIONS

New uses are continually being found for telecommunications. Banks, stock exchanges, hotel reservations, cable TV, hospitals, computer centers and other new customers are appearing at an increasing rate. We are literally in the midst of a global communications explosion.

The newest development that can help meet this demand and increase service is, of course, the communications satellite. It can supplement cable, radio, or microwave links where they exist, can provide their equivalent where they do not, and can, literally, interconnect every part of the world.

As this committee knows, the first successful communication satellites were Echo, Telstar, Relay, Syncom, and the Soviet Molniya. In 1965, the new Comsat Corporation launched Early Bird, and Intelsat, an international consortium, was created to handle global satellite communications. The viability and significance of satellite communications have been proven in the last 4 years, as Comsat's annual revenues have grown from $2.5 million to nearly $50 million.

This new benefit from the space program is obvious to TV viewers. The Olympics were first televised internationally in 1964 from Tokyo, and made available in real time to U.S. audiences. The largest audience in world history—over half a billion people, one-sixth of the world's population—saw man's first steps on the moon. In 1960, you could not send live TV across the Atlantic; by 1965 it was possible but expensive; by 1969 the quality has been improved and the cost reduced to 19 percent of the 1965 rate.

Current Intelsat satellites have a capacity of 1,200 two-way telephone circuits—or four-color TV channels; the next generation scheduled for next year will handle 5,000 two-way circuits. Present Intelsats already operate at 75 percent of capacity, and demand is increasing. The number of commercial ground stations is growing rapidly, too—from five in 1965 to 52 in 1971, with station cost decreasing from $15 million for the earliest to less than $4 million for current stations.

An example of new applications was provided last month by the 18th International Congress for Post-Graduate Medical Instruction, in which Dr. Charles Berry of our Manned Spacecraft Center participated. The American doctors stayed at Houston and San Antonio; their counterparts were in Switzerland, Germany, and Austria. Satellites provided closed circuit television and two-way voice circuits between the United States and Europe, enabling a reported 30,000 European doctors to hear and see the 3-hour transatlantic conference.

At present, communication satellites are largely used for transoceanic traffic, providing economical links across the Atlantic, Pacific, and Indian Oceans. They are having major impact. Before satellites, a west-coast-to-Japan cable circuit cost $15,000 per month; Comsat was able to offer this service at a charge of $4,000.

The recent decision by the FCC to entertain suggestions for a U.S. domestic satellite system opens a whole range of potential new services, including low-cost message, data, and television transmissions coast to coast—and anywhere in between. The feasibility of domestic service has been well demonstrated—and the response from industry to the FCC invitation indicates that the potential for the application of satellite technology to U.S. internal communications is very high.

The communication satellite is far more than a replacement for phone or wireless—it is a new kind of capability. After NASA's initial experiments, we turned over Syncom II and III to the Defense Department for their trans-Pacific communications requirements until they could meet these needs themselves.

As you know, the Department of Defense now has its own near-synchronous communications satellites in operation, as well as a tactical communications satellite. NASA has just launched the British Skynet and NATO–A communications satellites—both built in the United States—in support of joint Western defense needs. All of these systems trace their technical heritage to NASA's communications satellite programs.

ATS TEST FOR PUBLIC BROADCAST

NASA's applications technology satellite, ATS, is being used in a test for the Corporation for Public Broadcast, relaying educational programs from the east coast to the west coast. We also demonstrated the feasibility of using satellites for high-quality, reliable ship-to-shore communication over long distances by keeping contact with the SS *Santa Lucia* from New Jersey to Chile and back with the ATS.

The same satellite proved the feasibility of keeping in communication with aircraft on transoceanic flights—a major step toward future space-based air traffic control and navigation systems. We also have used the ATS to relay information from remote instruments and buoys—a step toward future data relay satellite systems. A future ATS will broadcast educational television directly into 5,000 Indian villages. Communication satellites thus have great flexibility.

The benefits to society of NASA's communication satellite work are widespread. Communications are the nervous system of organized society. Good global communications are not a luxury today—they are a basic building block for economic and social progress.

From our first experiments in the early 1960's to today, we have come far. Even the 240-circuit Syncom of 1964 already looks antique beside its 1971 descendant, the 5,000-circuit Intelsat–4. NASA has led the already dynamic electronics and telecommunications industry into a new age and provided them with a major new technology.

All of this has been accomplished and the 70-nation Intelsat organization created within 10 years. That fact, of itself, may be unique. The application of new technology has usually required far longer—it took a century for the electric motor to graduate from a scientific curiosity to a utilitarian device.

The NASA contribution has been to challenge and stimulate technical advance, forcing new inventions into the marketplace and making them work. This has a national value without a price tag. In my opinion, it is worth, simply, the difference between continuing national progress and falling behind into a position of second best, never again to catch up.

6. IMPACT ON MANAGEMENT

Another important class of achievement from NASA's programs is the demonstrated national capability to organize and manage very large, long-term, global technical enterprises—meeting difficult performance goals on schedule and within budget.

FORTUNE ARTICLE ON APOLLO PROGRAMS

Rather than discuss this complex subject in the limited time available here, I would like to place in the record, with your permission, Mr. Chairman, a recent Fortune article by Tom Alexander which puts this aspect of our program into proper perspective.

Senator CANNON. Without objection, it will be made a part of the record.

(The article referred to above follows:)

THE UNEXPECTED PAYOFF OF PROJECT APOLLO

(By Tom Alexander)

Even before the landing of men on the moon, now scheduled to take place this month, Project Apollo has already accomplished the main thing it was meant to accomplish. President Kennedy initiated it eight years ago as a perceptive leader's master stroke to restore the damaged self-esteem of a nation that had long prided itself upon technical proficiency. The very questions now often raised in criticism of the space effort—"If we can send men to the moon, why can't we eradicate pollution (or cure poverty or rebuild cities)?"—are in themselves tributes to how well Kennedy's particular objective has been not only attained but taken for granted.

Another valuable benefit of the moon program has been the fallout from it—though of quite a different kind from what most people had anticipated. Apollo was often touted as a substitute for war in forcing invention, but it seems unlikely now that much in the way of technology will emerge from the project that can begin to compare in significance with the innovations pushed into use by World War II: the digital computer, nuclear energy, jet propulsion, penicillin, DDT, and the rocket engine itself. Apollo's technological contributions are likely to be of subtle kinds—in techniques of metal forming, for instance, or in ways of obtaining a new order of reliability in complex equipment. To accomplish the moon landing within the time set by President Kennedy, Apollo's designers delberately hewed to techniques that did not reach far beyond the state of the art in the early Sixties. The really significant fallout from the strains, traumas, and endless experimentation of Project Apollo has been of a sociological rather than a technological nature; techniques for directing the massed endeavors of scores of thousands of minds in a close-knit, mutually enhancive combination of government, university, and private industry.

This is potentially the most powerful tool in man's history. Until now, the only obvious applications for a tool of this sort have seemed limited to something about as massive, imperious, and glamorous as space exploration or war. The question now is whether such techniques can be refashioned and turned to other tasks as well, to task as overriding in importance and difficulty as, for example, the management of the earth's complex ecological system, of which man is but one segment.

THE ART OF DOING WHAT YOU SAID

Apollo is by all odds the biggest, most dispersed, and most complex research and development project ever mounted. The Saturn V rocket development alone cost at least three times as much as the estimated cost of supersonic-transport development. Apollo draws upon a far wider spectrum of talents than any other peacetime effort in history. And despite all its baffling complexity, it cannot tolerate failure.

According to a favorite NASA saying, project management is merely the art of doing what you said you would. Eight years ago NASA planners assured the nation that they could send men to the moon before the end of this decade and perform the task for about $20 billion. The timetable appears likely to be met and the final runout costs of Apollo appear to be heading toward a figure of about $24 billion, very close to the quoted price when allowances are made for inflation. This figure includes, of course, all the costs of acquiring and building several entire installations and much hardware that will be used in a variety of space missions other than the moon landings. It also includes a limited follow-on program of manned earth-orbital experiments called the Apollo Applications

Program that will use surplus rockets and capsules from the moon program, together with some specially developed equipment such as an orbiting workshop and a large solar telescope.

By way of contrast, most high-technology programs—the F–111, the C–5A, the SST, and the Cheyenne helicopter being only the most recent and highly publicized examples—have overrun their initial stated cost estimates by large amounts, slipped their delivery schedules, and failed to meet their promised performance goals. The cost overruns in particular have naturally angered both Congress and the public, who thought they were buying on the basis of a quoted price and are legitimately outraged to find too late that the actual price is much higher. In the light of this, it is not surprising that space-agency people—a "NASA Mafia," as NASA Administrator Thomas Paine calls them—have been asked to solve problems in other government jobs. The agency's former deputy administrator, Robert Seamans, Jr., is now Secretary of the Air Force. Housing and Urban Development has former NASA Administrator James Webb's assistant engineer Harold Finger, in charge of Operation Breakthrough, the huge nationwide home-building program. James Beggs, former R. and D. administrator of NASA, is now Under Secretary in the Department of Transportation. And Philip Whittaker, who formerly supervised procurement activity for NASA, was recently transferred to the Defense Department to try to improve the contractual climate between the Air Force and its contractors.

The core of Apollo's human organizational machinery was the old National Advisory Committee for Aeronautics, essentially a scientific research organization with little management experience. To that was added the Army's ballistic missile team, of which Wernher von Braun's highly proficient V–2 rocket developers were the hard core. Other additions were the Navy's Vanguard Project and the Caltech Jet Propulsion Laboratory, plus numerous individuals such as James Webb, a former Director of the Budget, and Albert Siepert, now deputy director for management of the Kennedy Space Center, who was brought in from the National Institutes of Health. Then, after Apollo was initiated, NASA could brandish the sheer glamour of the moon-landing project at a time when there were few ongoing large military development programs, and thereby attract a wide variety of deeply experienced people, both civilian and military. Some of these, such as Brainerd Holmes, George Mueller, Lieutenant General Samuel Phillips, and Rear Admiral Roderick Middleton, had managed the development of big missile programs and early warning networks, which were the first of the large, complicated systems.

For a long time, to be sure, all this variety was a source of weakness in the moon program rather than strength. In the early days, along with other growing pains, Apollo's performance was impaired by distrust and jealous struggles for power among the various management approaches and particularly among the fiefdoms, the manned spaceflight centers at Huntsville, Kennedy, Langley, and later Houston. Bad feelings and cross-purposes persisted until well into the Apollo era, reaching a climax of some sort in the resignation of Brainerd Holmes, the fiery first director of the moon project. Holmes and Webb clashed over who should have the power of determining Apollo's pace. Accustomed to his previous independence as a czar on the Distant Early Warning Line project, Holmes regarded himself as running a race to the moon with the Russians. Many in NASA had been inspired by Holmes's forceful leadership, and after his departure morale sagged. Against this background it seems all the more remarkable that one of the most obvious attributes of NASA and its contractors today appears to be good will.

To a degree, this good will must derive from headiness over the prospects of success in a glamorous and difficult undertaking, a certified Great Event. But there is much more to it than that. One very important element is a relative absence of the kind of adversary relationship that often plagues defense projects nowadays. Apollo has spawned an intimate and potentially significant new sociology involving government and industry, an approach that appears to stand somewhere between the old arsenal concept favored by the Army and Navy and the newer Air Force concept that depends heavily upon private corporations to manage, develop, and build big systems. The NASA approach combines certain advantages of each, while enhancing the total abilities of both private and government organizations. The contracting firms contribute research capabilities, manufacturing facilities, and technical expertise, plus flexibility in staffing for special problems that the civil service economically match. The government's role is generally an integrating and directing one, but its lasting contribution

to partnership with the American aerospace industry has been to act as a central fund of deep experience and a point of transfer by means of which painfully acquired knowledge in managing and developing complicated systems gets from one company to another.

An essential foundation for this good will appears to be that NASA was able to avoid the strains of the "buy-in" syndrome. That syndrome, which afflicts most government procurement, is a product of two mutually reinforcing pressures. First, there is a government agency, say the Department of Defense, that badly wants an item of high-technology hardware. To get the program initiated, the agency goes before Congress with overly optimistic estimates on the cost of bringing to fruition a program full of unknown problems. This initial optimism is then compounded by the attitude of industrial bidders. Anxious to secure the contract (which in some cases might even mean the survival of entire corporations), most companies, too, have a built-in bias to buy their way into the contract with unrealistically low bids or with promises of high performance or fast delivery—promises that the agency often lacks the technical competence to gainsay. Aerospace executives, in their franker moments, sometimes refer to the process as a "liars' game."

DEVICES FOR RENEGING

Behind all the desperate optimism of the bidders lurks the underlying assumption that in all likelihood they will not be held strictly to their promises anyway. They reason that if any problems can be hidden until the program is far down the line, the government will be unwilling to terminate the contract or force the company into bankruptcy. From this mutual dependency emerge various devices for reneging on the strict letter of the contract, such as the "change order" or else the hiding of R. & D. overruns in the subsequent production contract. Change orders usually come about when the government decides to intervene and alter the design. Then parts of the contract become subject to a renegotiation, in which the contractor is in a far stronger bargaining position than he was in the first go-round. The result is often a "change in scope" and an increase in fee more than large enough to cover the financial risks the contractor took in his buy-in.

But for both the government agency and the company, this quasi-conspiratorial process usually has adverse and persistent side effects. It creates ill will and distrust between Congress and the executive agency and recrimination between the agency and the contractor.

Apollo was saved from all this by the fortunate fact that President Kennedy sold it to Congress and the nation before there were any detailed estimates of the cost of going to the moon. At that time, in the spring of 1961, about all that existed was a rough guesstimate of $20 billion to $40 billion. The nation bought it on that basis amid the peculiarly desperate enthusiasms of that spring, at a time when Americans were depressed by the apparent superiority of Soviet science and technology—including the just-demonstrated ability to orbit men—and by the involvement of the U.S. in the fiasco of the Cuban invasion. Later, when NASA's engineers had time to make more detailed cost estimates, the range they arrived at was $12 billion to $15 billion. But Jim Webb, with his Budget Director's seasoned political sense, was cognizant of the political dangers to his young organization if it lost credibility so early in the game. Applying what he called his "administrator's discount," he went before Congress with his own nontechnical estimate that the moon landing would cost about $20 billion. The happy result was that Apollo escaped all the budgetary strife.

THE TRAUMA OF THE FIRE

Still, it took the shock of a tragedy to weld NASA's government-industry team into its present remarkable form. The tragedy was the Apollo capsule fire in early 1967, in which three astronauts lost their lives. NASA and its contractors still tend to date events in terms of "before the fire" and "after the fire." Before the fire there had been the usual run-ins between NASA and the contractors—such as Grumman and North American and the Jet Propulsion Laboratory—over schedules, performance, and cost. But by and large, the agency was reasonably sure of its course. Suddenly everything changed; the white-hot, oxygen-fed flame of the capsule seared its way into the emotions of many people in Apollo, cauterizing old differences and forging a wholly new attitude that reached far beyond the technical steps taken to prevent a recurrence of fire. Not only was the entire

design of the spacecraft re-analyzed but the entire manned spaceflight organization and its attitudes as well. From this analysis emerged virtually a new organization, new states of mind, new approaches. Webb and his administrators came to realize that relationships with the contractors were defective and that the intercommunication they had fought so hard to obtain was not working as well as they had thought it was.

Some early tendency to shift blame for the fire upon North American Aviation was gradually supplanted by NASA's admission that the fire was largely its own management failure. NASA had overlooked and thereby in effect approved an inherent fault of design, namely the locking up of men in a capsule full of inflammable materials in an atmosphere of pure oxygen at sixteen pounds per square inch of pressure. NASA, after all, had more experience in the design and operation of space hardware than any other organization and was, therefore, more to blame than North American if the hardware worked badly. In any case the traditional relationships whereby one organization builds and sells hardware and another buys and operates it, while both stand at arm's length and jockey for contractual advantage, was no longer appropriate. NASA and its contractors, whether they willed it or not, were thrown together as allies against common foes—the hostile environment of space and the treachery of complicated machinery. The result is an intimate new sociology of space, a new kind of government-industrial complex in which each interpenetrates the other so much that sometimes it is hard to tell which is which. Frequently now the government and corporate participants in Apollo display an emotional—at times almost mystical—comradeship that seems unique in industrial life.

The most obvious example of this relationship can be seen at the Kennedy Space Center. Up through the days of Mercury and Gemini, the launches were carried out mainly by civil servants or military personnel. The government group at Kennedy is stil probably the world's most experienced team in the preparation and launching of space hardware. Yet now, when one looks in upon a firing room where an Apollo rocket is being counted down, most of the hundreds of check-out consoles that one sees are manned by contractor personnel, representatives of the various companies that made the hardware. But on a raised platform at the front of the room are forty-five consoles occupied by NASA people directing the whole operation. Of Kennedy's roughly 23,500 employees, only about 3,000 belong to NASA, and these perform over-all management functions. The operating work—everything from setting up schedules to sweeping floors—is done by contractor personnel. Dr. Kurt Debus, the over-all director of Kennedy, is a slight, quietly humorous man who was von Braun's chief deputy in the development of the V-2. Now sixty, he feels thoroughly at home in the sometimes turbulent environment of American aerospace contracting. "Throughout its first big contract here," he observes, "every company is mostly an apprentice."

HAZARDS IN THE STACK

The center has evolved some complicated social patterns to cope with its intermixture of responsibilities and loyalties. Most of the hardware contractors working at preparing a given Saturn-Apollo for launch are critically dependent upon one another's performance in adhering to their excruciatingly tight schedules. About 50 percent of the tasks performed in the preparation of a rocket are officially classified as hazardous. This usually means that when one contractor is doing such work in his part of the "stack," as the towering Saturn-Apollo assembly is called, no one else is permitted to work in it. So if one group's job takes too long, the entire operation suffers critically and the launch stands a chance of missing its "window"—its once-a-month launch opportunity. In fact, under the present schedule of one Apollo launch every two months, if one window is missed the entire future firing schedule also slips a month.

In this closely interdependent operation, no representative from one corporation can give another instructions—only NASA can do that—yet all their operations must be interwoven and coordinated in greatest detail. This is accomplished by elaborate schedules that spell out on virtually a minute-by-minute basis what every contractor will be doing in the stack. Schedules get adjusted in numerous meetings chairmanned by NASA overseers and attended by technical people from all the major contractors. The man who orchestrates all this activity is Rocco Petrone, the director of launch operations at Kennedy. Petrone, forty-three, a hulking, fast-moving, and thoughtful former Army officer, played tackle on West Point's famous Blanchard-Davis football team. Each week he holds a soul-

searching session with the men who head the contractor task forces at Kennedy. Actual and potential foul-ups are meticulously analyzed for their educational value. One recent session was partly devoted to a postmortem of the accidental draining of the kerosene fuel tank of the Apollo 10 Saturn rocket while it was on the launch pad undergoing a preliminary checkout. The vacuum created by the draining fuel slightly dimpled the tank, briefly raising worries about its structural integrity. After discussing the incident with those present, Petrone voiced his conclusion that if anyone was at fault, it was NASA management at Kennedy—and by implication his own office.

In other sessions, occurring daily, NASA and industry technical people meet in one of Kennedy's empty firing rooms and go over the impending schedule with virtually minute-by-minute attention. Each contractor reports how well he is hewing to his part of the over-all schedule that in bar-chart form occupies an entire front wall of the huge room. Information on delays and unscheduled hazards is thereby conveyed to all those present and schedules are adjusted accordingly. From time to time, Petrone or his staff members employ a firm but gentle needle upon a contractor whose slippage or faulty performance threatens the entire launch schedule. "Management by embarrassment" is Petrone's description of the characteristic approach at the space center. The goldfish-bowl visibility in which all the Apollo contractors operate makes this an effective method. "We'd be terribly embarrassed if we held up a launch," says one company's manager at Kennedy.

But it might also be expected that the unaccustomed role of chastised apprentice at Kennedy and elsewhere could grate upon the pride of these traditionally independent American industries. Actually, the reverse seems to be true in Apollo. The industry teams at Kennedy display a loyalty to the Apollo effort that must be something of a perplexity to corporate heads back home. An example is Grumman's George Skurla, who directs the preparation, checkout, and launch of the manned lunar module at Kennedy. "Sometimes when I go back up to headquarters at Bethpage," he says, "they ask me who I think I work for, Grumman or NASA. But I say that regardless of the corporate badge, we've got an obligation to the program and to NASA." He has differences with NASA, too, sometimes. "We've got to stand up and call the shots as we see them. They're paying for our experience. The pressure is excruciating—all the managers work under the subconscious strain of something going wrong. NASA hounds us sometimes, but they also perk us up when we need it. In my twenty-five years in the aerospace business, this is the most fascinating job I've ever had—or ever will have."

With much of the same earnestness, Austrian-born George Low, the Apollo program's manager at Houston, speaks of the new government-industry partnership as "a very rewarding experience." One of the original planners of the moon mission, Low is an outwardly gentle engineer who replaced Joseph Shea as program manager after the spacecraft fire. During NASA's post-fire introspection, Low decided that far more openness and involvement in each other's affairs were needed between NASA and the spacecraft contractors. On his side, Low has granted the contractors unprecedented access to his deliberations. "All the contractor people here know that I conduct no meetings with my own people where they are not welcome, the exception being Monday morning staff meetings. The contractors get involved in every decision concerning the program here. It has taken a while to get them to believe we really mean it, though."

The other side of the coin is that NASA insists upon being deeply involved in everything concerning Apollo that goes on within the contractors' organizations. Not only does NASA have teams working within the contractor plants, monitoring quality, costs, and schedules, but once each month Low and other members of his organization fly to both North American and Grumman and spend a long day at each company going over engineering and schedule problems in excruciating detail. Like other NASA managers, Low is now convinced that the moon program, with its forbidding stakes and risks, cannot rely upon normal incentives to assure that schedules and quality standards are met. They realize that when managers—corporate or otherwise—begin running into trouble, an instinctive reaction is to attempt to hide it and hope for some miraculous solution.

"Before the fire," he says, "there probably wasn't enough talking between us. And too much of what there was had to do with negotiating contracts instead of solving technical problems. Now we simply trust each other. The negotiators know that, too; they know we won't be unfair."

It is legitimate to wonder how well these new relationships would work in a program without the limelight and prestige of Apollo. Moreover, NASA's govern-

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ment team for Apollo is unusual in being, if anything, more knowledgeable than industry about space engineering, so the two sides can meet in an atmosphere of mutual professional respect. This situation does not often exist in other programs, and industry is sometimes resentful when civil-service engineers or managers meddle or impose unrealistic requirements.

There is some danger in all this that the generally competent and innovative American aerospace industry could become simply a job shop to government. The companies could end up in the situation of the old-fashioned American shipyards, which relegated the design function to the Navy's former Bureau of Ships or to outside naval architects, and thereby lost the production efficiencies that accrue when designs are drawn with producibility in mind.

DAMPING THE WAVES OF TROUBLE

An enterprise such as Apollo constantly teeters on the knife edge of managerial disaster. In many different places, many things are going on at once that impinge closely one upon the other. If a perturbation occurs in one place, the result could be self-reinforcing oscillations throughout the whole system, tearing it apart. For example, there is the matter of weight. Naturally, the lifting power of the Saturn V rocket sets an upper limit to the weight of the Apollo system. But there is more to it than that. Going to and from the moon, for instance, the man-carrying Apollo spacecraft and lunar modules use other small rockets of several sorts for propulsion, braking, and guidance. If a capsule turns out to be, say, only one pound heavier than originally planned, it may need as much as ten pounds of additional fuel aboard to provide the necessary steering or braking power. But the weight of the extra fuel in turn could overshoot the Saturn V's lifting capability and require that weight be taken out of equipment being built somewhere else. The ultimate result might be extremely expensive reworking of already existing hardware, slipped schedules, and perhaps compromised reliability.

Apollo is full of such sensitivities, with respect to not only weight and performance but also cost, scheduling, and reliability. The key to Apollo management is that there can be none of the luxury of "wait and see." Problem trends must be spotted and damped out before the spiraling process sets in.

Probably the most frequent word in the Apollo managers' vocabulary is "visibility." What it refers to is the constant effort to know everything that's going on, to approach omni-science. Obtaining visibility has been a long process, full of backing and filling, stepped-on toes, and much fretful pondering over whether the process is hobbling Apollo instead of advancing it. The result has been to break new management ground and create an organization that is a strange mixture of rigid formalism and casual disregard for the hierarchies symbolized by conventional organizational charts.

Basically, the moon program functions as a "projectized" organization, a concept instituted by Dr. George Mueller (pronounced "Miller"), who replaced Brainerd Holmes in early 1964. A former professor of electrical engineering, Mueller brought some of his managerial ideas from the Air Force ballistic-missile program, which he worked on before joining NASA. Slim, pragmatic, and quietly steely, he stands in sharp contrast to both the loquacious, nontechnical Webb, a man given to speaking in hazy generalities, and the erudite, philosophical Tom Paine. (Not the least of the remarkable things about NASA is that it manages to stay intact with so many strong-willed individuals operating with so many differing styles.) To aid in his reorganization of Apollo and to run the day-to-day operations, Mueller was able to borrow the Air Force's Lieutenant General Samuel Phillips, a former vice commander of the Ballistic Systems Division and manager of the highly successful Minuteman I missile program. Phillips, an erect, sandy-haired native of Wyoming, is notable for his ability to impart meaning to the opaque, alphabet-soupy jargon that has sprung up within the field of project management.

SERVING TWO MASTERS

First developed by the military services in connection with large systems, "projectization" has evolved in Apollo to the point of being a management revolution. It carries to its most elaborate development the "task force" concept now becoming the fashion in management doctrine. Under projectization, a separate Apollo Program Office was established in each of the three government field centers—the Manned Spacecraft Center in Houston, the Marshall Space

Flight Center in Huntsville, and the Kennedy Space Center at Cape Kennedy—as well as on the premises of the main contractors—North American, Grumman, Boeing, Chrysler, I.B.M., AC Electronics, and McDonnell Douglas. Each program office has positions for such functions as design, schedule, finance, and quality control that parallel those in the main program headquarters in Washington. In effect, these offices form a separate network for command and communication outside the main NASA organization to monitor all Apollo work with respect to schedule, cost, performance, and quality, and, of course, to ensure that all the pieces will indeed fit together when they finally meet for the first time at Cape Kennedy.

But the end result of projectization is an interwoven structure whose lines of responsibility and communication reach out in several directions. It departs from many of the principles of classical management theory, including unity of supervision and responsibility and rigid hierarchies of command. Each of the program offices at both the center and contractor organizations must serve two masters, the Apollo program and the organization itself. In cases of conflict over directives, appeals are brought to Mueller, who is not only in charge of manned space flight, but is also over-all chief of the three centers as well.

FAME IS THE SPUR

One of NASA's highly formalized tools for attaining visibility is called FAME (for Forecasts and Appraisals for Management Evaluation). The heart of FAME is a series of several hundred constantly updated charts dealing with such matters as weight, schedule, performance, and cost for each of the stages in the Apollo system. Each chart has an estimated or calculated limit above which weight or cost, say, in any given stage cannot rise without having adverse effects throughout the whole system. During the design, development, and fabrication of each stage, new data is fed into computers, which are programmed to translate the widly gyrating data into smooth trend curves that predict whether the limit will be exceeded at some point in the future. When such a trend is spotted, some level of Apollo management usually institutes what is called a "buy-off." It is usually possible to buy off a weight problem, for instance, by substituting lighter structure, or by discarding some item of equipment. The price will probably be added cost, but may also be exacted in the form of lower reliability or limitations of the mission. In general, the earlier the buy-off is made, the less the penalty.

Another aid to visibility is "configuration management," which helps ensure that engineering and mission decisions—buy-offs, for example—made at one nodal point in this Apollo network do not have perturbing effects elsewhere. This discipline is exerted through a hierarchial set of Change Control Boards, beginning at the manufacturing plant level and continuing upward through the NASA centers to the manned space-flight headquarters in Washington. Rigid rules specify the kinds of changes that can be made in hardware, software, or mission at each level without approval from a higher board. For example, a manufacturer and its in-plant Apollo program office together might be able to change the size of a bolt on a space capsule without prior consultations with a higher board, but not the location of a fuel inlet, because this could affect the location of the umbilical arms on the launch tower at Cape Kennedy.

VISIBILITY VIA COMMUNICATIONS

A common essential to all these approaches to the problem of visibility is rapid, continuous, and assured communication. NASA has probably the most communication-conscious management in history. The entire nationwide organism jangles with communication—via telephone, data link, Telex, formal conferences, and by people simply leaning into doorways and talking to one another. One means of ensuring the communication that enables projectization, FAME, or configuration management to work at all is dedicated documentation. Everything—every technician's task, every test, every lot of every material, every component—has a formal document associated with it that can be used to feed information to a higher level, to fix responsibility, or to trace a component or material failure and prevent its reoccurrence. Someone has computed that the ongoing management of Apollo involves the use of some 10,000 different reports, forms, graphs, and documents. In addition, NASA publishes dozens of manuals for its internal use and thousands of technical studies and reports, becoming

quite a respectable publishing operation in consequence. A standing joke among the new space-system managers is that when the weight of the paperwork equals the weight of the space vehicle then you know you're ready to fly.

Perhaps the most impressive contribution of a strictly technological nature is reliability. Apollo's reliability is the product of three elements: a management philosophy that places overriding emphasis on the safety of the men aboard; a design philosophy requiring that for every component whose failure could imperil the lives of astronauts or the mission itself there be some kind of "redundancy," or alternative means of performing the function; and finally sophisticated equipment that permits detection of potential failures on the ground. Ground testing of flight hardware consumes approximately 35 percent of Apollo's entire budget.

Using past experience as their guide, Apollo's early planners assumed that they would have to expend a half dozen or more of each of the rockets and space capsules in the process of "man-rating" them—i.e., certifying them as actually ready to carry men. Three generations of rockets—called Saturn I, Saturn IB, and Saturn V—were designed. The first two were to be used merely to test the manned-flight modules while the vastly larger Saturn V was being developed. But as it has turned out, both Saturn I and Saturn IB have been all but superfluous to the program. Saturn V came along so fast and in such a well-documented environment of visibility and confidence that instead of six or seven unmanned firings of these $185-million beasts only two were required. (By contrast, the Air Force fired thirty-one Atlas missiles before attaining an operational system, and Wernher von Braun's German team fired nearly 1,200 test V-2's.)

Along with the greater design experience and painstaking documentation, the Saturn developers had highly sophisticated computerized equipment that permitted incredibly searching tests on the ground, together with "all-up" testing in flight—i.e., launches of all stages at once rather than piece-meal. One of the byproducts of Apollo has been a considerable number of unused Saturn IB's and space capsules that now can be employed in the Apollo Applications experiments.

IT TAKES MORE THAN STYLE

Upon first peering into the clockwork of the Apollo organization, the outsider may feel a little dismayed by its rigidities: things like configuration management smack of what is otherwise known as bureaucracy and all the documentation seems difficult to distinguish from red tape. Many of Apollo's own engineers chafe under such requirements, which they sometimes feel to be peripheral and time wasting. In any case, most of the managers in Apollo seem to agree that the real key to success lies not in the specific formal procedures but in the operational style—the dedication, excruciating attention to detail, and mutual cooperation among a variety of talented and strong-minded individuals.

In most endeavors, it is true, the full array of formal procedures such as FAME and configuration management would constitute a costly form of overkill. But when an endeavor reaches an Apollo-like scale of size and complexity—as more and more social and environmental projects must—then a full panoply of system disciplines becomes useful and perhaps even indispensable. If what NASA and industry have learned about management in the moon program can lead to better ways of pooling diverse abilities for very large tasks—perhaps to putting rationality into man's relationships with his global environment—then the $20-odd billion price of Project Apollo could turn out to be a splendid bargain.

SPACE AGE URBAN MANAGEMENT ARTICLE

Dr. PAINE. I think the article analyzes thoughtfully NASA's contribution to the Nation's growing management competence to accomplish what we set out to do. It is the writer's view that this benefit from the space program is as great as all the other values combined.

We are often asked whether NASA's management techniques can be applied to urban problems, and with your permission I will also fur-

nish for the record a short paper which discusses space age management and the urban complex.

Senator CANNON. Without objection, it will be done.

(The paper referred to above follows:)

SPACE AGE MANAGEMENT AND CITY ADMINISTRATION

(By Thomas O. Paine, Administrator, National Aeronautics and Space Administration)

(This is an edited version of a paper delivered by Dr. Paine at the National Conference on Public Administration, Miami Beach, Florida, May 20, 1969.)

"If we can go to the moon, surely we can vastly improve our cities here on earth." This simplistic but oft-repeated complaint is a non sequitur. Mobilizing modern science, technology, and management to accomplish bold ventures in space is clearly far simpler than better organizing the extraordinarily complex human interactions that comprise a modern metropolis. NASA's sepectacular advances in space are undoubtedly exacerbating public frustration with urban failures, but at the same time they are encouraging the nation to tackle its more complex human problems with greater confidence on a bolder scale. If America can go to the moon, it can indeed do much better here on spaceship earth.

In his paper, General Samuel Phillips described NASA's advanced management system for the Apollo Program, one of the boldest and most complex projects man has ever undertaken. Within the diverse enterprises of our nation's space program there are also many other management systems. NASA's range of management approaches is nearly as broad as the range within an urban complex. In this paper some of the significant similarities and differences between NASA and cities will be pointed out, and comparable management problems indentified. The optimum approaches to these problems will be classified on a "spectrum of management" scale, with a considerable overlap suggested for NASA and cities. The essential point is that components of NASA and urban institutions each require appropriate institutional architecture for successful problem solving within complex environments. The viability of these ever-changing institutional patterns must be a primary concern of these responsible for our space program and our complex urban society. Although managing the Apollo Program is obviously very different from running a city, NASA's broad managerial experience does have relevance for urban administrators.

SIMILARITIES BETWEEN NASA AND CITIES

Let us begin by examining some of the similarities between NASA and cities. In an obvious way, both are large and complex human systems involving hundreds of thousands of people and billions of dollars. Both involve the dynamic interaction of innumerable individuals, groups, and institutions; both are mechanisms for sensing, integrating, and solving a great diversity of interrelated problems. Each in its own way is a "public" enterprise that exercises public responsibility, requires public support, and must operate in the "goldfish bowl" of public review and criticism.

In a somewhat deeper vein, for both human enterprises, technology has become the engine of change—the "pacing item" around which many other considerations are scaled. For NASA the surge of new technology is something deliberately created and immediately utilized. For cities, the recognition of technological change is often reluctant, and its social impact seldom foreseen. Cities often act like victims reacting to technology, rather than beneficiaries welcoming and fostering needed advances to solve new problems. In any event, the winds of social and technical change are having a remarkable impact on both NASA and urban society. They are creating new leadership opportunities—opportunities which should attract competent men who understand how to direct new technology and new management capabilities in the public interest.

DIFFERENCES BETWEEN NASA AND CITIES

Having pointed out a few ways in which NASA and cities are similar, I must now concede that there are also many important ways in which they differ. Basically NASA is concerned with physical systems and "hardware"; cities are concerned with human systems and "software." NASA's interests might be

thought of as narrow and future-oriented, in contrast to those of cities which tend to be broad and oriented to the past. NASA can define specific, stated, measurable goals, articulate them, and demonstrate obvious success to its public. Cities have at best very general objectives, many of which are undefined and unmeasurable, some of which cannot be stated in any operable way, and are subjects of passionate public dispute. More importantly, NASA's end products respond to, and are tested against, natural laws which are rational, systematic, codified, and well understood by its professionals. Where they are not understood, the power of modern science is called in to rectify the situation. Cities, on the other hand, have their report card marked against wobbly success standards involving prejudice, special interest, wishful thinking, conflicting values, loose rhetoric, prophecy and revelation, or, in the current vernacular—SOUL. A social theory to guide urban society is nonexistent—or worse!

In a fundamental sense, NASA is oriented toward problem solving and rapid technological change. We are expected to undertake bold enterprises, to be innovative, and to experiment with unproven approaches to solve new problems. Although this is challenging, we can see what works and what does not, and arrange for a direct feedback of this knowledge to the action controllers running the enterprise.

In contrast, the city is fixed in place physically and legally, with a static structure, old traditions, and hardened institutional relationships. Its people tolerate weak, divided, and ineffective governmental organization because they are usually wary of changes that might alter the existing power balance, and suspicious of innovation and experiment. Most importantly—the social science which should provide the social theory to guide urban experimentation and "score" its successes and failures has not yet matured. This makes the information feedback to the fractionated city halls and urban agencies impossible to rationalize and substantially less useful for corrective action. Improved urban decision making in the public sector is a major unsolved problem in today's society.

One final important difference between NASA and cities should be mentioned. To a considerable extent NASA picks and chooses the participants in its programs and competitively selects those best fitted for each needed contribution. The criteria for admission are high motivation, competence, and institutional effectiveness. NASA has been able to meet these criteria, and has attracted some of the best talents in the country to contribute to its achievements. NASA pays its people, and in return demands continuing excellence of performance and commitment to the objectives of the Agency. NASA is an organization which encourages individual independence and initiative, but it must also insist on the highest order of technical discipline, for its work is tested in an unforgiving and harsh environment.

Cities, on the other hand, can erect no standards of motivation, competence, or effectiveness for admission, impose no terms and conditions for continued participation—and charge taxes for the ride! Since the golden age of Pericles in Athens, the punishment of exile has gone out of style, although high modern standards of mobility allow individuals to "vote with their feet" and move away from unattractive urban environments.

THE SPECTRUM OF MANAGEMENT

The preceding brief discussion of some similarities and differences between NASA and cities was obviously not intended to tout NASA or denigrate cities. Rather, I sought to compare these two kinds of large and complex human enterprises from the manageability standpoint by considering a few of their essential characteristics. If we had a well-understood "spectrum of management," I believe that NASA would tend toward one end of the scale, and an urban complex toward the other, but there would be a large overlapping area. One end of this spectrum of management might be called the "Digital Discipline" or "Punched-Card Management" end, characterized by organized, disciplined, and highly structured human activities, strongly oriented toward specific numerically statable goals. We seem to know best how to manage activities at this end of the spectrum. Examples from cities are the communication and power services furnished by AT&T and Consolidated Edison; the Apollo Program is a NASA example.

At the other end of the spectrum we find what might be called "Darwinian Discipline" management. This is appropriate for institutions which society can best "manage" by arranging an environment within which the competing com-

ponents fight it out in a Darwinian manner to see which will best adapt and survive. Individual enterprises which survive in NASA or cities will continue to mutate and evolve in ways which frequently defy description, much less top-level hierarchal management. The "products" of enterprises at this end of the management spectrum may be measurable only in terms of the human spirit.

Urban examples of this kind of institution include New York's galaxy of fine restaurants, and the entrepreneurs of Hong Kong. Nothing could be more Darwinian than the survival of individual gourmet restaurants—heaven forbid that they be taken over by a chain. Likewise the net effect of Hong Kong's entrepreneurs has been an extraordinary economic "takeoff" for that city, which has provided a remarkably effective solution to the mayor's problem of absorbing a continuing influx of refugees. Hong Kong has survived as a city in very difficult social and political circumstances because of its rigorous economic system within which a yeasty ferment of entrepreneurial enterprises can compete for capital. No charismatic czar of business development is elected to switch capital and manpower from plastic toys to transistor radios.

An example of a NASA activity appropriately managed by "Darwinian Discipline" is the science of astrophysics. Here also is a rigorous intellectual discipline within which individual professors select new research areas and publish their results for critical anaylsis. The most exciting and productive men attract the brightest new graduate students, and astrophysics moves on into new theories and new fields. Hierarchial control by a czar of astrophysics, or anything resembling this in NASA's support of university programs, would be disastrous.

There are many obvious ramifications of these rather abstract observations which cannot be developed further in this brief paper. The principal point is that the urban manager, like the NASA manager, must consider carefully the wide diversity of activities that must be orchestrated within the total urban complex or space system. The institutional architecture of each component of the total system must be selected from the spectrum of management—from "Digital Discipline" to "Darwinian Discipline," from Consolidated Edison to Le Pavillon, from Project Apollo to astrophysics. Structural changes must be introduced with changing technology and social trends.

For example, the thousands of "old law" tenements in Harlem built to house sweatshop immigrant workers more than half a century ago are utterly obsolete in this age—rehabilitated or not, rent-controlled or not—as are the disgraceful neighborhoods in which they stand. The job of replacing them is before us. What are the important human values, urban goals, and public expectations here? What new institutional patterns can best achieve the various objectives? What resources will be required over what period? How can the contributions of universities, industry, and government be organized? What approach from the "spectrum of management" is best for each component? How will the required new scientific understanding be acquired through theory and experiment? What technological advances should be fostered and utilized? As the work progresses, how are the experimental results to be fed back to the action controllers? Here is an urgent urban management problem worthy of the nation that conquered the moon. Obviously the job cannot be managed like Apollo, but I believe that NASA's broad experiences in space-age management do have applicability.

Thus, in NASA and in cities the nature of the work to be accomplished varies widely; both the NASA manager and the urban manager must seek the best institutional architecture for components within the total complex. The appropriate choice from the spectrum of management often changes with time. For example, an urban transit system, garbage removal service, or cable TV system might best be operated by competing private companies or a single company under franchise during one period, be run by the city using municipal employees at another stage, set up as a non-profit corporation or authority at a third time, and at a fourth time let out to support-service contractors under periodic competitive bid. Technological change will alter the relative desirability of these approaches as, for example, bus transport replaces electric street cars, electric disposals replace garbage cans and trucks or radiating TV links replace cables. Few cities today have the managerial structure and resources to take early advantage of technical opportunities, much less to foresee new possibilities and deliberately bring about needed technical advances applicable to urban systems. This is anachronistic in these times, and can only lead to deteriorating services and soaring budgets. The new federal Department of Housing and Urban Development is seeking to rectify this.

What does this condensed and somewhat abstract discussion mean to the urban manager grappling with the immediate problems of his city? Several significant points might be made from our NASA/urban management comparisons:

First—many of the most important activities in the city cannot and should not be managed in the "Digital Discipline" sense of that word. The urban manager, like the NASA manager, can and should directly manage only a limited part of the complex interacting human enterprise for which he has responsibility. For the important remainder he must structure a "Darwinian Discipline" system to encourage essential contributions from industry, from universities, and from the entrepreneur, the free wheeler, the scientist, the brilliant innovator, the gifted teacher, and other committed individuals. In no other way can execellence be achieved in the French chef and astrophysicist, the Broadway producer and spacecraft designer, who, with thousands of other individuals, set the quality of urban and space enterprises. Perhaps the most difficult task we have is to conceive and establish the appropriate institutional architecture to achieve this. The greatest single achievement of the space age may have been the formation of NASA; the rest followed as the energies and talents of America were released and given direction.

Second—it is in the nature of the job for the high-level public adminstrator to help define and articulate goals in the public interest. If there is to be any consensus of social values and goals in a city, they must be based on the urban manager's understanding and leadership of the city's amorphous and frequently conflicting forces. From his understanding of the environment, the urban manager can decide realistically what he can manage and where he can lead, identifying those areas of activity which need to be moved toward a different management approach, and effecting the required changes. Nothing could be more difficult, but changes must be made.

Third—even when a city activity is capable of being directly managed in a "Digital Discipline" fashion it is still important to select the appropriate form of institutional architecture for the job. It is essential to define specific objectives and goals and to relate the resources required to each area of management activity. The planning-programming-budgeting technique, though no panacea, can be helpful here. Objectives should serve as targets for achievement and not be treated as fixed and immutable commitments. Objectives (like NASA's moon landing) are vital, however, for two purposes:

1. They provide a vital focus and communication tool for continuing discussion among the many forces at work in the urban environment. Through this discussion the objectives themselves can be flexibly altered and upgraded with changing conditions and available resources.

2. Goals are also a necessary prerequisite to the use of the powerful tools of systematic management which are being demonstrated and further developed now in business and government.

A vital consideration in creating the appropriate institutional architecture for complex management tasks is a realistic appraisal of the resources required to achieve the goals, and the creation of appropriate organizational mechanisms for close control of these resources. This organizational mechanism will probably have to be innovative in terms of its level and placement in the city structure and the nature of its authority. Much more attention must be paid to experimentation, communication, organizational interactions, and real-time feedback of results, rather than to line operating authority alone.

Fourth—a fatal flaw in a complex human enterprise operating in the modern environment of technical and social change is to freeze its institutional architecture. "Horse and buggy" institutions and jurisdictional boundaries must be overhauled and updated. We must get on with this task even without a guiding theory. We should also get to work on a useful social theory. It had better be one which not only permits, but encourages experimentation and feedback in the mechanisms of urban management, and which allows for failures in the experimental process. Almost everything that happens in a city happens to all its citizens. It is perhaps fortunate that city residents are inevitably becoming more concerned and involved. This provides the urban manager with a "sputnik-like" opportunity to marshal public concern now into a new commitment to an urban renaissance in America. As with the space program, new federal and local management institutions must be created based on the realities of today's metropolitan areas. Major resources must be administered under close control, orchestrating the best talents of universities, industry, and government to apply the great power of modern science, technology, and management.

Meanwhile, America should continue to forge ahead boldly in space. Our new space achievements will further spur us on to create here on the good earth tomorrow's great new urban society.

Dr. PAINE. Let us now turn to the processes by which these benefits are obtained.

7. INFORMATION FLOW PROCESSES

NASA has taken the lead in developing positive new processes for the documentation and transfer of scientific and technical information to those who can use it. Our technology utilization program documents innovations from all NASA centers and industrial contractors which may find use in a wide range of other applications. To date, over 18,000 individual technology items have been so identified, with over 3,000 documented in our widely used "Tech Briefs"—of which 38 million have been sold and distributed.

WALL STREET JOURNAL ARTICLE

This program is described in greater detail in appendix 1 and in a recent Wall Street Journal article, which you may wish to include in the record.

Senator CANNON. That will be made a part of the record.

(The article referred to above follows:)

[From the Wall Street Journal, Mar. 27, 1970]

SPACE FALLOUT: DATA BANKS CONTAINING NASA RESEARCH FRUITS HELP MANY COMPANIES; RESEARCH OF $35 BILLION EFFORT AVAILABLE AT A LOW COST; LOCKHEED, LITTON USE FILES; BUILDING A BETTER OSCILLOSCOPE

(By A. Richard Immel)

William Ferwalt runs a seven-man company that makes oscilloscopes on the Nez Perce Indian Reservation in Idaho. He wants to know everything he can about oscilloscopes, so last fall he paid $190 for a computer search of the National Aeronautics and Space Administration's technical data bank.

For his money, he got the fruits of five years of oscilloscope research done by Bendix Corp. under Government contract. The data included hitherto overlooked techniques for building a special type of instrument.

Mr. Ferwalt expects to parlay his $190 into $100,000 in sales, thereby doubling his company's business over the next several years.

Ferwalt Inc. is one of an increasing number of businesses taking advantage of the $35 billion spent on research for the nation's space program. The companies get their information at any of six data dissemination centers designed to open NASA's extensive technical data resources to private industry.

600,000 DOCUMENTS

The first center was established seven years ago at Indiana University. Since then, centers have opened at the universities of Connecticut, New Mexico, Pittsburgh and Southern California and at North Carolina Science and Technology Research Center. The centers are financed by NASA and the money coming in from clients.

By NASA estimate, the data centers bulge with nearly 600,000 research documents; 6,000 documents are being added every month. Much of the data is generated by a clause in NASA contracts that requires companies to report to NASA any inventions and technology developed in the course of their Government work. But the data bank taps other sources, too, including the Department of Defense research files and professional journals and technical papers from around the world, including Communist countries.

Although the benefits are most striking for small companies with little research capability of their own, such large firms as Litton Industries and Alcan Aluminum are paying $1,000 to $5,000 a year to use the data banks. Even giant

Lockheed Aircraft, a major aerospace contractor, is finding it can get some technical information faster through a dissemination center's computers than from its own voluminous research library. For several years, Lockheed has been going to the center at the University of Southern California to keep up with new techniques in metal welding and nondestructive testing.

A MAJOR MISCONCEPTION

In all, some 400 companies used the centers last year. That's up considerably from a few years earlier, but it is still far too small a number, NASA officials say. The nonprofit centers could easily handle work for thousands of clients, the officials say.

NASA officials caution that the data banks aren't the answer to every struggling businessman's dreams. "A big misconception we have to fight is that we're a grab bag of treasures," says an official. "We can only tell if an idea is feasible, if it can be done within the realm of costs. The idea has to be in the client's head before he comes to us."

A. Kendall Oulié, director of the center at Southern California, agrees. "What we're selling here is access—the use of computer and search capabilities," he says.

The centers employ a small full-time staff of engineers and clerical help and hire engineers and scientists on a part-time basis to sit down with clients and develop a computer search strategy. It is this personal attention that is at the heart of the centers' effectiveness, clients say.

PERSONAL CONTACT

"We have access to the same NASA tapes through Washington," says Horace Jacobs, a Lockheed official. But, he says, the data centers' advantage is that they assign a person or two to discuss and work with a scientist. "There's more personal contact."

Although it is possible to get a one-shot computer search similar to the one the oscilloscope maker got, the centers encourage clients to sign up for a full year's services, drawing against the retainer of $1,000 to $5,000.

The most popular service for clients is a retrospective computer search of the entire data bank, tailored to answer a client's specific question. For $190 the computer will spew out condensations of technical reports describing all the work that has ever been recorded in the data bank on that particular subject. Then, for another $300, the client can get a "current awareness" search each month, which keeps him up to date on new material being added to the bank.

For $80, a company with less specific needs can, order a "standard interest profile," a list of condensations printed up periodically by the centers on a wide range of topics of fairly general interest.

Clients say the service is often fruitful. Dart Industries, a manufacturer of housewares, plastics and drugs, says it is developing high-temperature coatings for its consumer cookware as a result of a retrospective computer search.

Company officials say they also consult the computer before making decisions about new ventures. "When we're probing new business areas for Dart we need a quick reading to find out if a particular technology" has consumer applications, says Joseph Ciarimboli, Dart's manager of technical planning. "So we go and get a quick computer readout."

The Dart executive admits, however, that he was skeptical at first. "It took us about a year to be convinced," he says, adding, "People in the field tend to think they're up on everything."

Dr. PAINE. This kind of transfer works as follows: for a small fee, an entrepreneur can have a computer search made of NASA's extensive technological data banks in his own field of interest, and can then apply the results within his company to develop new or improved products or services in a minimum time at low cost.

NASA INFORMATION SERVICES

NASA's information services are also available to schools and colleges, as described in appendix 3. An even more important effect of the space program on U.S. education has probably been the stimulus

it received to improve standards to meet the challenge of the space age. As the President's science adviser, Dr. Lee DuBridge has said:

One hundred years from now the new kind of knowledge attained in space research will surely have paid untold, unforeseen, and unexpected dividends. Already, the dawning of the space age had impelled Americans to seek to improve their schools. That alone may be worth the cost of all our space rockets.

NASA's greatest contribution to U.S. education, however, has undoubtedly been the information academic researchers have received from our direct involvement of the university community in the U.S. space program. What these scientists and graduate students learn in the pursuit of their research feeds back immediately into the teaching, publication and learning process, thus becoming available to the new student generation and technical community.

The 37 NASA-supported research facilities illustrated in appendix 4 have greatly helped our universities carry out their all-important work as full partners in the U.S. space program.

COMPUTER INFORMATION FIELD

NASA has also developed an effective mechanism to make Government-originated computer programs readily available to other potential users. This service, called Cosmic, is saving subscribers who pay for the service at least 90 percent of the cost of developing new programs for their particular applications. This important area is described more fully in Appendix 1.

Another effective capability we have developed in the computer information field we believe represents a breakthrough in international data exchange. Through its information-exchange agreement with the European space research organization, ESRO, NASA has established an American-European computer-based information storage and retrieval system for the international aerospace community.

Supplementing longstanding document exchange procedures with ESRO, the NASA/Recon system for on-line, remote-terminal access to aerospace literature is probably the most advanced in the world. From a central computer located in Darmstadt, Germany, this powerful system is serving scientists through remote terminals in Paris and Brussels; additional terminals are being installed to extend the network. All major NASA field centers also have terminals.

ESRO's use of the NASA/Recon system involves the processing of master machine-stored indexes regularly provided by NASA in return for ESRO's contribution of European aerospace literature in preprocessed form for automatic input to the central NASA scientific and technical information collection. This exchange relationship with ESRO is a unique element in NASA's wide-ranging international exchange program—involving nearly 300 governmental, academic, and research organizations in some 50 foreign countries. By providing machine-system linkages on an international basis, it furnishes the foundation for the development of further advances to serve the world aerospace community.

NASA PUBLIC INFORMATION EFFORT

At the same time, NASA devotes much effort to keeping the public informed about our program activities, our successes—and our failures—our discoveries, achievements, and results. We make it possible for television audiences around the world to participate in man's exploration of the moon, and for the world press to tell the story promptly and accurately.

We answer nearly a million public inquiries annually. NASA exhibits were seen by over 37 million people last year—and at the Osaka Expo this year the United States pavillion featuring space will draw another 15 million people. More complete data on our public information coverage is included in appendixes 5 and 6; what I want to stress is that I believe we have done an unmatched job of public education in bringing the facts of our highly technical space program to the general public at home and abroad.

8. EXAMPLES OF NASA TECHNOLOGY TRANSFER

I have described the direct outputs of NASA's efforts to move new information into the public domain and to see it put to use. There are many additional dividends from our space programs for which NASA should only claim partial credit. These dividends, variously called spin-off, fallout, or technology transfers, should be looked at in proper perspective.

Some are real, some are prospective, some are still to be tested in the rigorous climate of a competitive marketplace. In appendix 1 we have documented some 200 examples of such dividends or byproducts of the space program. They range over many fields: medicine, materials, safety devices, electronic instrumentation, manufacturing and test techniques, tools, fire-resistant foams, and paints.

Some may only find limited application; others may in time become the nucleus of new industries. In my opinion, however, the major justification for space exploration remains its first-order benefits to science, to technology, to new direct applications, and to future U.S. wealth and power. Some of the byproducts might have been developed in time without a space program, but we have at least accelerated the process by providing the challenge, and then systematically gathering, cataloging, and disseminating the resulting technical information to the people who can put it to early use.

Thus the exhibits here today certainly do not purport to provide a self-evident justification of the Nation's space program; they represent only a very small sample of the recent transfers from aerospace technology. I would like to describe a few of them now.

AUTOMOTIVE SAFETY DEVICE

One example is an automotive safety device which originated in an experimental astronaut couch shock absorber. The device here on display consists essentially of an inner tube with O-rings around it fitting tightly into an outer tube. When compressed or extended, the rolling O-rings absorb considerable energy. The device is rugged, cheap, resettable, and reusable.

The Bureau of Public Roads has tested it in connection with highway guard rails, and found that it cuts down a 60-mile-per-hour impact to the equivalent of a 5-mile-per-hour impact. Perhaps the most impressive testimonial to its utility is the Ford Motor Company's intensive development effort aimed at incorporating this device into an automobile bumper that can safely withstand a 5-mile-per-hour direct impact. The company hopes to offer this bumper as soon as possible—perhaps on its 1972 models.

The economic significance of this becomes apparent when you relate it to the Allstate Insurance Company's announced collision premium reduction of 20 percent for cars so equipped.

Another automotive-related benefit is, I am sure, familiar to you: grooved highways for reducing skidding accidents, illustrated in the display. NASA's work on aircraft tire hydroplaning led to grooving airport runways—the Washington National runway was grooved in 1967—and the same equipment is now being used on dangerous sections of highways in 18 States. Reported results are an 80- to 90-percent reduction in damage, injury, and death from skid accidents.

NASA DEVELOPMENTS IN MEDICAL FIELD

In the medical field, NASA developments have found a number of direct applications over a wide spectrum of problems. One is the use of computer techniques—developed to improve Mariner-Mars planetary photographs—to enhance the clarity of clinical X-rays, shown in the exhibit before and after enhancement.

Others are illustrated in the display of biomedical instrumentation developed at our Ames Research Laboratory. A small commercial item is the emergency lightweight blanket here on exhibit. It weighs almost nothing and has found considerable favor among sportsmen. Made of aluminzed Mylar—the same material used in the Echo balloon satellites—it reflects 80 percent of the wearer's own body heat.

The small "pinger" on display was developed to help us find space vehicles that have fallen into the ocean. The system is directional: when water closes the contact of the battery-powered onboard element, it emits "pings" which can be detected by a surface detector, enabling a search party to find the submerged object.

The FAA is considering including these devices in the automatic flight logs of transoceanic airplanes, so that in the event of a crash, the log can be recovered and the cause of accident established.

Incidentally, we have a recent example that this device really works. During the March 7 eclipse, an NRL Aerobee payload malfunctioned during reentry and was lost at sea. The "pinger" operated for 5 days and led the Navy recovery team to the spot. Using their latest deep-water techniques, they then retrieved the payload from a depth of 6,000 feet.

NASA'S SEARCH FOR FIREPROOF MATERIAL

The last item on display here really represents an entire field: fireproof and fire-retardant materials. NASA's search for a family of materials that can be used safely in an oxygen environment has led to the development of fireproof textiles, foams, plastics, and paints that hold great promise for commercial and industrial use.

Airlines, for example, are studying the use of these materials to reduce the possibility of cabin fires and the Navy is experimenting with a NASA foam to protect aircraft fuel tanks from incendiary bullets.

I have briefly recounted some of the solid, fundamental benefits that have accrued from the Nation's space program—benefits to our citizens, to the Nation, to mankind as a whole, and to world stability. I have touched on the NASA process which effectively translates scientific discovery and technological capability into progress.

It is an extremely complex process involving little understood interactions; no methodology for modeling or describing it has been developed. But we do have an intuitive feeling for how it works, and we can see the significant multiplier effects of our space program on our economy and society in the large.

The process will remain dynamic as long as we maintain an energizing current of new ideas, new techniques, new challenges to stimulate its operation. In my opinion the process has been and continues to be successful; it is creating far more than it is costing.

The exhibits here today tell only a very small part of the story, but they show you a representative sample of our published output and some examples of typical technology transfers.

The best exhibits NASA could have here today, to convey to you in more dramatic terms the achievements and values produced in the last decade, would be an Intelsat III communications satellite and a large high-speed computer, a Saturn V rocket and a Nimbus weather satellite, a Boeing 747 and a 210-foot-diameter tracking antenna. Perhaps the best exhibit of all would be to pile up $28 billion representing the aerospace industry's order backlog, or assemble on the Capitol grounds the 50,000 gulf coast residents whose lives might have been lost to Camille without weather satellite detection and tracking. These and hard, tangible results from America's space program.

9. FUTURE PROMISE OF SPACE PROGRAM

Let me touch briefly now on the future promise of the space program as we see it. One of the important new developments of great potential that should be mentioned is NASA's earth resources technology satellite program. The first steps in this program are experimental, aimed at learning what we can monitor from space.

Multispectral photographs and sensor data from Apollo flights and from specially fitted aircraft are providing the initial inputs. By combining the information gathering capabilites of space systems, the data transmission capabilities of satellites, and the high-speed data processing and large memory of the computer, we can foresee these promising first experiments growing eventually into a new global environmental information system geared to human decision processes at every level. It will have major economic value.

We will know enough about global weather to be able to modify it locally and perhaps to alter regional climates. We will also know enough to understand the second and third order implications of such actions, and will be able to act accordingly, in concert with the world community.

We will better understand the intricate processes of the oceans, and their ability to produce our food and to absorb our pollutants.

We will know our North American freshwater systems well enough to manage them effectively on a continental scale, neither wasting nor hoarding this vital resource.

Our management and use of dry land—for agriculture, forestry, recreation, and living space for tomorrow's larger population—will be based on the view we can only get from space. We will better understand the internal mechanics of the earth—and be able to measure their effects well enough to predict earthquakes and volcanic activity early enough to avoid loss of life. We will better understand the distribution and utilization of the earth's mineral resources.

AIR, SEA, AND LAND TRAFFIC CONTROL

Navigation and traffic control, for air, sea, and land, will increasingly rely on space systems. Satellites will carry the majority of the world's communication traffic, from telephone calls and computer networks to graduate lectures and television meetings. TV broadcasting and switching functions will be done in orbit.

Transportation will be more convenient, quiet, rapid, and safe, and the present city-suburb-country complexes will be greatly modified by integrated transportation systems that permit the most efficient use of time and facilities without central city congestion.

We will have increasingly productive facilities in space, perhaps for manufacturing and medical treatment; certainly for astronomy, biology, physics, and earth studies. We will explore the solar system, first with instruments, then with man. We will unlock new fundamental doors to knowledge, and will be able to use that knowledge for the benefit of man on earth.

This perspective is not overly optimistic; history too often has shown us that our predictions fall far short of what actually happens. In less than a generation we may have progressed well beyond these forecasts. As Chairman Anderson has pointed out, we are only limited by our own imagination.

CRITICAL REEXAMINATION OF SPACE PROGRAMS

It seems to me that in recent months we Americans have been engaging in a national contest of critical reexamination of our space program, which I believe is right and good. It is perhaps typical of us that we want to hang a price tag on everything and then haggle over prices as though we were shopping in an ancient eastern bazaar. But we don't want to carry this to the point where it will be said of us that we know the price of everything but the value of nothing. Our national self-examination of the space program has evoked widespread discussion, some thoughtful, some superficial, some informed, some ignorant of the facts. The best discussion has been in your hearings, in my opinion, where we have built a historical record that has placed before the American people what NASA has committed to accomplish, when we intend to do it, and how much it should cost.

NASA is proud of its record of working with you to set bold objectives before the American people, and then publicly meeting the test to see whether we accomplish the objectives on time and within budget. I know of no other Government activity that can match the record of the space program.

We seem, however, to come inevitably to the dollar questions: What has it cost? What should it have cost? Would the money have been better not spent, or expended on other things "here on earth"?

Without repeating the obvious fact that indeed all NASA's dollars are spent on earth, my reply to these questions is that we are getting more than our money's worth, and must press forward vigorously both in the space program and here on earth. These are not mutually exclusive, but mutually supporting enterprises.

SPACE EFFORT COST ONE-HALF PERCENT OF GNP

The United States has been spending more and more of its tax dollars to effect social change: in schools, in welfare programs, in health programs, in poverty programs—and has also been spending tax dollars in NASA to effect technological change.

The former involves the redistribution of existing resources, the latter involves the creation of new resources. The social account is far larger and growing rapidly. Last year's growth alone added to the social accounts the dollar equivalent of two whole NASA programs, and the President's fiscal year 1971 budget proposal is to increase the social accounts by 2½ NASA's.

In hard, cold facts, our space effort over the decade has cost this Nation less than one-half of 1 percent of our gross national product, and in return it has made a major contribution to the growth of our GNP from $440 billion in 1958 to $900 billion in 1969. I would submit that our $450 billion growth in GNP is clearly the principal factor that has made possible our social advances.

Reviewing Federal budgets from 1959–69, we find that the United States has spent $1.4 trillion, and of that figure, the NASA's program has cost $35 billion, only about 2½ percent of Federal spending. I am firmly convinced that the many resulting benefits to our Nation and to mankind everywhere far outweigh this modest investment. I cannot imagine where America—and the western world—would be today had Americans not undertaken to meet the challenge of space.

We are still at the beginning of the space age. Despite many impressive achievements, our present systems are crude indeed by the standards of tomorrow's space shuttle, space station, nuclear propulsion, and science and application spacecraft.

Let us continually reexamine the direction and pace of the American space program, increasing the thoughtfulness and intellectual content of the debate, by better understanding the benefits to America and mankind. With this knowledge, let us press boldly forward to explore this endless frontier that now lies within man's reach.

SPACE EXPERIMENT REGARDING CANCER

Senator CANNON. Thank you, Dr. Paine, for a very fine and very comprehensive statement. The exhibits that have been made a part of the record will also be very helpful, I am sure, and also the exhibits that you have on display in the room here.

I intend to make a floor statement today advising the Senate that these exhibits will be on display here for 2 days so that people who may wish to do so can come by and see them.

A few weeks ago NASA announced an outstanding discovery by

one of its scientists, Clarence D. Cone, Jr., who heads the Molecular Biophysics Laboratory at Langley Research Center. Mr. Cone has in essence discovered that the voltage on the surface of a cell is directly related to cell growth and that cells with small, negative membrane voltage divide at maximum rates. You referred to that in your statement. This finding may explain the fundamental reason for the uncontrolled growth of malignancy, and if the theory proves valid, its implications on the cancer problem are indeed profound.

If there is no objection I will put in the record at this point, a NASA news release concerning this and a news article from the San Diego Union that refers to it.

(The information referred to follows:)

THEORY HELPS EXPLAIN CANCER GROWTH

A space scientist has devised and demonstrated a theory that helps to explain the source of uncontrolled malignant growth and indicates short cuts to the development of chemical countermeasures against cancer.

The scientist is Clarence D. Cone, Jr., head of the National Aeronautics and Space Administration's Molecular Biophysics Laboratory at NASA's Langley Research Center, Hampton, Va. He specializes in the investigation of space radiation effects on the blockage of cell division.

Cone described his new theory on cell division to the 12th Annual Science Writers Seminar of the American Cancer Society today in San Antonio, Texas. This is the second year in a row that Cone has been invited by the society to tell the science writers about one of his research accomplishments.

Cone's paper, "Control of Cell Division by the Electrical Voltage of the Surface Membrane," explained his theory and told how it had been experimentally verified in Langley laboratory tests.

The Cone theory proposes that the division of body cells (a normal process that goes on continuously), is controlled precisely by the pattern of ion concentrations on the surface tissues of cells. The pattern is formed by the electrical voltage that normally exists across cellular surfaces and varies from one part of the body to another.

This theory has provided, possibly for the first time, an explanation of the functional connection between the two major pathological features of cancer—uncontrolled growth of cells and the spread of the disease in the body.

Cone said the theory implies that the basic functional aberrancy—deviation from normalcy—producing both of these conditions lies in an alteration of the molecular structure of the cell surface.

Cone explained the electrical aspect by detailing recent Langley studies concerned with space radiation blockage of cell division.

In that research, he noticed that cells having large negative membrane voltages seldom if ever divide while cells with small negative electrical potential divide at maximum rates.

This led Cone to propose the theory that the cellular ionic concentrations, which generate electrical voltage, determine whether or not a cell will divide. A comprehensive experimental test revealed that ion concentration differences between membranes did indeed exert a powerful control over cell division.

The Cone theory proposes a central mechanism for control of body cell division, which, if it proves to be generally valid, will provide a powerful new basis for research progress on many key biomedical problems, such as human conception, birth defects, growth, aging and particularly, cancer.

"In essence," Cone observed, "it explains the fundamental source of the uncontrolled growth of malignancy, knowledge of which should lead to a number of new approaches to cancer control."

The deadliness of cancer arises from two abnormalities characteristic of all malignant cells: their uncontrolled proliferation and their ability to metastasize—spread to other parts of the body—and invade normal surrounding tissues.

Previously, there has been no known relationship between these two characteristics, although they always occur together. Cone's theory and experimental observations on the electrical voltage-level control of cell division imply that these two properties of cancer cells are intimately related.

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A fundamental implication of Cone's research is that the primary change which occurs when a normal cell is transformed to a malignant one consists of a basic functional change in the molecular architecture and special characteristics of the cell surface.

This surface abnormality acccounts for two primary features of cancer: the decreased adhesiveness of the cells (allowing them to invade and spread) and the lowered electrical voltage level which permits the unrestrained growth.

The changes in molecular characteristics which accompany malignant transformation produce what may be descriptively termed "molecular amnesia" of the surface; the malignant cells are thus unable to recognize and relate to their environment of normal and/or other malignant cells. The cells seem to "think" molecularly that they are in a semidissociated state approaching that of tissue culture.

The step-by-step theory of Cone proposes (1) that metabolically induced and stabilized cell surface polymer (molecular structure) alterations play the central role in malignancy, (2) those changes cause decreased surface adhesion and lowered electrical voltage levels with attendant metastasis and active proliferation; and (3) the lowered voltage level then feeds back to stabilize and sustain the very metabolic pathways which act to produce it.

If the Cone concepts are generally valid, the implications for cancer control are significant, for attention is now focused on a specific component of the cell, the surface complex, and on a particular aspect of metabolism—that concerned with surface polymer production and assembly.

Cone sees the need for a greatly increased understanding of the cell surface complex, leading to possible new methods of attack on malignancy.

The scientist suggested a short cut in the complex study of the metabolic pathway alterations which ultimately lead to surface abnormalities in malignant cells. By studying cancer viruses which have only four or five genes, it should be possible, he said, to determine which genes are producing what surface abnormalities and even to map the associated metabolic changes which take place in the course of malignant transformation.

Once the specific surface abnormalities are identified, they can then be looked for in other forms of cancer, and chemical countermeasures to their malfunctive properties can be developed.

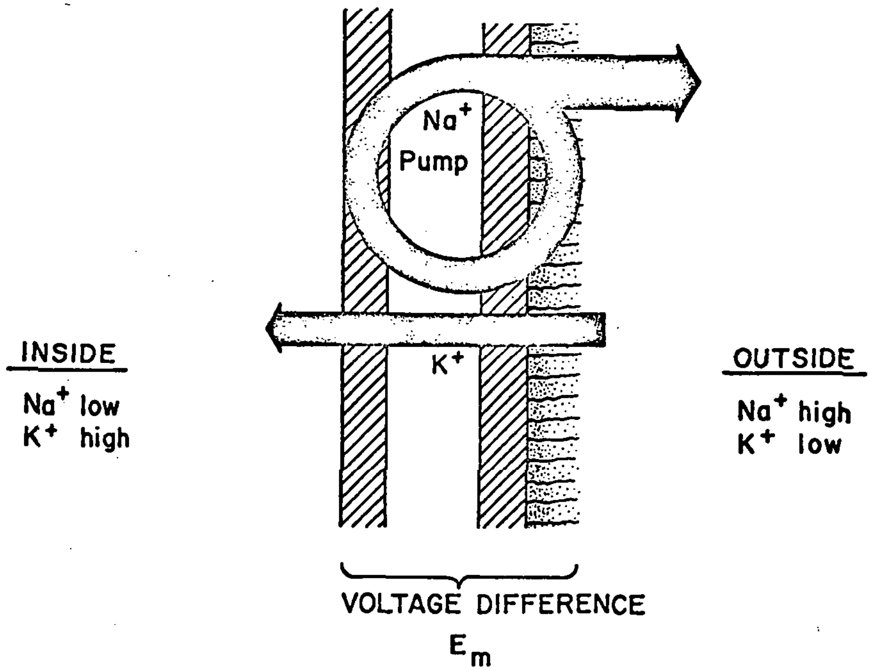
In 1969, Cone, 38, reported the discovery of intercellular bridges that may help in understanding the behavior of certain types of cancer. This previous discovery by Cone has been serving as the basis for further study by scientists to determine if these cell linkages exist in, and possibly constitute the basic cause of uncontrolled proliferation in any types of human cancer of primary medical importance.

Cone's scientific contributions to the solution of the cancer problem are spin-offs from his basic investigation in the field of space radiation.

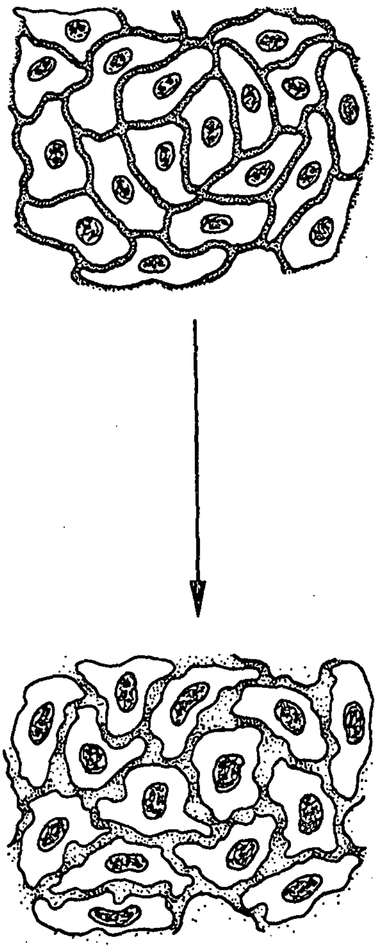
Basically a chemical engineer (Georgia Institute of Technology), Cone also has a Master's degree in aeronautical engineering (University of Virginia).

In addition to his molecular level studies in cellular biophysics, Cone has engaged in research on various aspects of avian biophysics and natural aerodynamics, particularly the aerodynamic theory of soaring and flapping birdflight on which he is an international authority.

Cone, a native of Savannah, Ga., joined the Langley staff in 1956. He lives in Yorktown, Va.



Each normal cell of the human body possesses a surprising degree of negative electrical charge produced by active pumping of positive sodium ions out of the cell. This removal of sodium ions generates a substantial electrical voltage (E_m) across the surface membrane; this voltage can be accurately measured by inserting ultramicro electrodes into the cell, and serves as a convenient indication of the degree to which the ionic concentrations, primarily those of sodium (Na^+) and potassium (K^+), differ between the inside and outside of the cell.



NORMAL CELLS

1. Cell surface bonding strong.
2. Cells remain in place.
3. Electrical voltage level high.
4. Cells divide at low rate.

MALIGNANT CELLS

1. Cell surface bonding very weak.
2. Cells mobile, spread and invade normal tissue.
3. Electrical voltage level low.
4. Cells divide at rapid pace.

[From the San Diego Union]

SPACE SCIENTIST SUSPECTS CANCER'S "SWITCH" ELECTRICAL

(By Cliff Smith)

SAN ANTONIO, TEXAS.—A Space Agency scientist reported experiments in which he was able to turn the process of human cell division on and off at will.

The scientist, Clarence D. Cone Jr., sees his research as a solid lead toward learning how the cell division switch is held "on" in cancer.

"In essence," he said, "it explains the fundamental source of the uncontrolled growth of malignancy, knowledge of which should lead to a number of new approaches to cancer control."

If the theory proves valid, the scientist said, "its implications for the cancer problem are particularly profound."

Cone heads the Molecular Biophysics Laboratory at the Langley Research Center in Hampton, Va. He reported his work for the first time at the 12th annual American Cancer Society seminar for science writers here.

NEGATIVE VOLTAGES

While searching for clues to how space radiation damages cells, Cone said, he found that the rate of cell division varies in relation to the electrical voltage present in the cell membrane.

Specifically, Cone said, he found that cells having large negative membrane voltages seldom if ever divide while cells with small negative levels divide at maximum rates.

By varying the concentration of sodium and potassium of human cells grown in culture dishes, Cone said he can regulate the membrane voltage and secondarily the rate of cell reproduction.

The primary characteristic of cancer is uncontrolled, runaway proliferation of the malignant cells.

Cone said his experiments suggest that "the sustained proliferation of malignant cells appears to be due to the fact that they are permanently electrically depolarized and possess only a fraction of the negative membrane voltage level of their normal counterparts."

"The implications of these concepts . . . for cancer control are significant (and) could lead to new methods of attack on malignancy.

"For example . . . chemical treatments which would act to raise the negative membrane voltage level specifically of the aberrant cells would prevent tumor growth."

Cone said he measured membrane voltages by inserting ultramicro-electrodes into cells.

"Each normal cell of the human body possesses a surprising degree of negative electrical charge produced by active pumping of positive sodium ions out of the cell," he explained. "This removal of sodium ions generates a substantial electrical voltage across the surface membrane."

POINTS TO "TRIGGERS"

Cone theorized that "any of the wide range of chemical, physical or viral carcinogenic agents (agents causing cancer) can be the trigger setting off the critical cellular disturbance which ultimately results in the functional alteration of the surface structure."

Cone said he established in his experiments that "the blockage of (cell) division resulted from a prevention of synthesis of DNA," the basic genetic material of all forms of life. He said, however, that he believes that cellular membrane voltage changes precede the changes in DNA.

Cone carefully acknowledged that, even though his experiments provided apparent proof that membrane voltage potentials regulate cell division, his concepts must be regarded only as theory.

He noted, however, that all his findings so far are "in full accord with the theory."

NASA EFFORTS IN POLLUTION PROBLEMS

Senator CANNON. I have also noticed recently that the Governor of Texas requested of NASA some assistance in dealing with the problems of pollution and preservation of the national resources and environment of Texas. Of course, NASA has agreed to provide whatever assistance it can.

Without objection I will place in the record a couple of news stories about this. I think this is an excellent example of cooperation between the Federal and State authorities to attack some of our environmental problems.

(The information referred to follows:)

[From the Houston Chronicle]

AIRCRAFT SATELLITE SENSOR DATA: NASA AGREES TO AID STATE POLLUTION FIGHT

AUSTIN.—The National Aeronautics and Space Administration will assist the state in dealing with the problems of pollution and preservation of the natural resources and environment of Texas, Gov. Preston Smith has announced.

The governor asked NASA administrator Dr. Thomas O. Paine in February to—give the state access to "the vast wealth of scientific information stored in the Earth Resources Data Bank at NASA's Manned Spacecraft Center in Houston."

In response to the governor's request, Paine said Dr. Robert Gilruth, director of MSC, and members of his staff "stand ready to meet with your staff to provide the appropriate data." Paine said the data would include "remote sensor data derived from aircraft and satellites over Texas and its coastline."

The Earth resources survey program is a cooperative undertaking of NASA and the Departments of Interior, Commerce, Agriculture and the Navy.

During this decade, Paine said, NASA will launch a series of Earth resources technology satellites to acquire remote sensor data.

The governor's division of planning coordination will work with the Earth Observations Division of NASA and assist in communicating pertinent data to the appropriate state and local agencies.

[From the Houston Post, Mar. 22, 1970]

NASA ACCEPTS REQUEST

AUSTIN.—Gov. Preston Smith said the National Aeronautics and Space Administration has responded favorably to a request that it let Texas' pollution control program benefit from the space program.

In a letter to NASA Administrator Thomas O. Paine in February, Smith asked that NASA provide photographs and other information pertinent to pollution control and natural resource development. He asked for access for pollution control purposes to "the vast wealth of scientific information stored in the Earth Resources Data Bank at NASA's Manned Spacecraft Center in Houston."

Smith said he had received a reply from Dr. Paine that Dr. Robert Gilruth, MSC director, and members of his staff in the Earth Observations Division in the Sciences and Applications Directorate "stand ready to meet with your staff to provide the appropriate data."

Members of the governor's Division of Planning Co-ordination will work with NASA's Earth Observations Division and assist in communicating data to appropriate state and local agencies, Smith said.

He said NASA's co-operation "will be most helpful and effective in dealing with the urgent problems of pollution in Texas."

Dr. Paine said "remote sensor data derived from aircraft and satellites over Texas and its coastline" will be among the data furnished.

He said that during this decade NASA will be launching a series of earth resources technology satellites to obtain remote sensor data that will contribute to a NASA goal of helping control pollution to preserve the environment.

NASA WORKS WITH STATES

Senator CANNON. Dr. Paine, if the Governors of other States are interested in some assistance from NASA, who would they contact and how would they go about getting such assistance?

Dr. PAINE. Mr. Chairman, if the Governors contact me directly, they will certainly get a very rapid response. NASA is working closely with the Office of State Technical Services in the Department of Commerce and also with the State technical service organizations throughout the country at the State level. Our Regional Dissemination Centers (RDC's) have been particularly active in working with State centers. In fact, the Director of our Regional Dissemination Center in New Mexico is also the Director of the New Mexico State Technical Service Office. In Indiana, our RDC Director is the associate director of the Indiana State Technical Service Office.

So we welcome inquiries from the States, Mr. Chairman, and can indeed work closely with them.

Senator CANNON. Would you furnish the precise address for the record at this point for those that might be interested?

Dr. PAINE. Fine. The precise address is the Administrator of the National Aeronautics and Space Administration, Washington, D.C. 20546.

STUDY NATION'S TRANSPORTATION REQUIREMENTS

Senator CANNON. I note in your statement you refer to some of the progress so far as transportation was concerned and I am wondering if you are working closely with DOT on this integrated transportation system philosophy.

Dr. PAINE. Indeed we are, Mr. Chairman. The Department of Transportation and NASA are working at the present time on a joint study of the Nation's transportation requirements for the future. It is staffed by both the Department of Transportation and NASA personnel and we hope to be able to report the results of this study to this committee in the future.

PUBLIC INFORMATION ON SPACE BENEFITS

Senator CANNON. You have given us an excellent idea of the truly broad scope of the benefits that the Nation and the world are receiving from our space program. What can be done to bring that information to the American public so they will understand better the worth of the space program?

Dr. PAINE. This is a problem, as I indicated in my testimony, that is receiving a great deal of attention in NASA. The fact that our more spectacular missions tend to outweigh the more mundane story of benefits is one of the problems that we face here. Our very success is making it more difficult for us.

I think what we require here is effort across the board on the part of NASA to find more effective ways of getting the story across. We certainly also appreciate the support that we have had from various people on this committee who are familiar with the NASA story of benefits. The speeches that they have made, both on the floor and other places, have, I think, been of much assistance in getting this story across but it is a very difficult story to tell.

Senator CANNON. You refer in appendix 5 to the fact that in calendar year 1969 speakers were provided for some 2,049 nontechnical groups reaching an audience of some 265,000. Does NASA have a speakers bureau as such where all such requests can be referred?

Dr. PAINE. We have a speakers bureau both on a centralized basis but also around the country at the various NASA centers. In addition we receive tremendous quantities of requests for astronauts to appear before various groups and this is handled centrally from Washington because of the tremendous demand and the fact that it is necessary for us to turn down so many of these requests. But if we can't furnish the speaker that is requested, we try to offer an alternative speaker or a film so that we meet the requests in some manner at least.

Senator CANNON. Is any consideration being given by NASA as to how this particular segment of the public could be reached on a broader scale? In other words, people who could be reached through civic and municipal organizations and persons whose daily life doesn't ordinarily bring them into contact with this sort of thing?

Dr. PAINE. We rely very heavily on the American news media. The television channels, of course, have tremendously effective ways of getting the message out and we furnish them material suitable for release by TV. We furnish the newspapers with a great deal of material on this and I think in the future our task is undoubtedly to make this material more newsworthy, more attractive and more likely to get first-class attention on the part of the public.

ADDRESSES FOR NASA INFORMATION

Senator CANNON. We hope to print the record of this hearing soon and we hope that it will receive wide public dissemination. For the benefit of those who read it, would you place into the record at the appropriate point the addresses to which the interested readers should inquire if they desire to obtain further information?

Dr. PAINE. Fine. I will do that, Mr. Chairman.

(The information submitted for the record follows:)

NASA TECHNOLOGY UTILIZATION OFFICERS

Assistant Administrator for Technology Utilization, National Aeronautics and Space Administration, Code U, Washington, D.C., 20546, 962–4636.

Director, Technology Utilization Division, National Aeronautics and Space Administration, Code UT, Washington, D.C., 20546, 963–7925.

Technology Utilization Officer, Ames Research Center, Mail Stop N-200–12, Moffett Field, Mountain View, Calif., 94035, AC 415/961–1111 ext. 2301.

Technology Utilization Officer, Flight Research Center, Box 273, Edwards, Calif., 93523, AC 805/258-3311 ext. 500.

Technology Utilization Officer, Goddard Space Flight Center, Code 207.1, Greenbelt, Md., 20771, AC 301/474–6242.

Technology Utilization Officer, NASA Pasadena Office (JPL), 4800 Oak Grove Drive, Pasadena, Calif., 91103, AC 213/354—6420.

Technology Utilization Officer, John F. Kennedy Space Center, Code AD–PAT, Kennedy Space Center, Fla., 32899, AC 305/867–2544.

Technology Utilization Officer, Langley Research Center, Langley Station, Mail Stop 103, Hampton, Va., 23365, AC 703/827–3281.

Technology Utilization Officer, Lewis Research Center, 21000 Brookpark Road, Cleveland, Ohio, 44135, AC 216/433–6832.

Technology Utilization Officer, Manned Spacecraft Center, Code BM–7, Houston, Tex., 77058, AC 713/483–3809.

Technology Utilization Officer, Marshall Space Flight Center, Code A&TS–TU, Huntsville, Ala., 35812, AC 205/453–2224.

Technology Utilization Officer, Space Nuclear Propulsion Office, Technology Utilization Branch, Mail Stop F–309/U.S. AEC Building, Germantown, Md., 20545, AC 301/973–3354.

Technology Utilization Officer, Wallops Station, Code AMD–SP, Wallops Island, Va., 23337, AC 703/824–3411 ext. 536.

COMPUTER SOFTWARE MANAGEMENT AND INFORMATION CENTER—COSMIC

Director, COSMIC, University of Georgia Computer Center, Athens, Ga., 30601.

REGIONAL DISSEMINATION CENTERS—DIRECTORS

Director, Aerospace Research Applications Center (ARAC), Indiana University Foundation, Bloomington, Ind., 47401.

Director, Knowledge Availability Systems Center (KASC), University of Pittsburgh, Pittsburgh, Pa., 15213.

Director, New England Research Application Center (NERAC), the University of Connecticut, Storrs, Conn., 06268.

Director, North Carolina Science and Technology Research Center (NCSTRC), P.O. Box 12235, Research Triangle Park, N.C., 27709.

Director, Technology Application Center (TAC), University of New Mexico, Box 185, Albuquerque, N. Mex. 87106.

Director, Western Research Application Center (WESRAC), University of Southern California, Los Angeles, Calif. 90007.

NASA PUBLIC AFFAIRS OFFICERS

Assistant Administrator for Public Affairs, Office of Public Affairs, NASA Headquarters, Washington, D.C. 20546, AC 202/963–5302.

Public Affairs Officer, Ames Research Center, Moffett Field, Calif. 94036, AC 415/961–1111 ext. 2671.

Public Affairs Officer, Flight Research Center, P.O. Box 273, Edwards, Calif. 93523, AC 805/258–3311 ext. 221.

Public Affairs Officer, Goddard Space Flight Center, Greenbelt, Md. 20771, AC 301/982–6255 or 4955.

Public Affairs Officer, Jet Propulsion Laboratory, 4800 Oak Grove Drive, Pasadena, Calif. 91103, AC 213/354–7002.

Public Affairs Officer, John F. Kennedy Space Center, Kennedy Space Center, Fla. 32899, AC 305/867–2201.

Public Affairs Officer, John F. Kennedy Space Center, Unmanned Launch Operations, Western Test Range, P.O. Box 425, Lompoc, Calif. 93438, AC 805/866–1611.

Public Affairs Officer, Langley Research Center, Hampton, Va. 23365, AC 703/827–3966.

Public Affairs Officer, Manned Spacecraft Center, Houston, Tex. 77058, AC 713/483–3671.

Public Affairs Officer, Marshall Space Flight Center, Huntsville, Ala. 35812, AC 205/453–0031.

Public Affairs Officer, Michoud Assembly Facility, P.O. Box 29300, New Orleans, La. 70129, AC 504/255–2605.

Public Affairs Officer, Mississippi Test Facility, Bay St. Louis, Miss. 39520, AC 601/688–3341.

Public Affairs Officer, NASA Pasadena Office, 4800 Oak Grove Drive, Pasadena, Calif. 91103, AC 213/354–6486.

Public Affairs Officer, Nuclear Rocket Development Station, P.O. Box 1, Jackass Flats, Nev. 89023, AC 702/986–5723.

Public Affairs Officer, Wallops Station, Wallops Island, Va. 23337, AC 703/824–3411 ext. 248.

Public Affairs Officer, Lewis Research Center, 21000 Brookpark Road, Cleveland, Ohio 44135, AC 216/433–4000 ext. 415, 438, 782.

Senator CURTIS. Mr. Chairman, would you yield right there?

Senator CANNON. I am very happy to yield.

NASA FILM LIBRARY

Senator CURTIS. In reference to material you provide for television stations, I think that is very fine. The local broadcasting station has to sell advertising to stay in business. Many fine educational programs are used but they are used at odd hours. They are used when the competitive television station is broadcasting a football game that everybody is watching, or early in the morning, or at a time of day when they have to have an affiliate. Sometimes their intentions are good and someone comes in and buys the time.

I say this as no criticism of the broadcasters. They have to run the free programs at the time that nobody else wants. The reason no one else wants it is because they have very few viewers.

In this way do you have a film program that tells the same story where many, many copies of film can be created and be made available not only for schools and civic clubs but for local meetings of many kinds where they want the NASA story and it is impractical or expensive to get a big name from the space program to appear.

I am sorry I took so long to ask my question but I thought it fitted in with what you asked.

Dr. PAINE. Senator Curtis, we do have a film library which contains films that tell not only the more dramatic stories of each Apollo mission but also that are specifically aimed at the direct benefits from the space program and these do receive wide distribution.

Last year we had a card in each film that we lent out to different groups to send back to us saying what the size of the audience was that saw that particular film. When we added these up at the end of 1969, some 9.8 million people had sat and watched a NASA film of some description.

Senator CANNON. I might say that I had some personal experience with that just a few weeks ago when NASA furnished one of the newer astronauts, Major Fullerton, and a rather short film from the Apollo 11 shot, which was narrated by Major Fullerton. We had it for the purpose of a women's luncheon group covering about 400 women initially, but he was able to get there in such time that we also visited two high schools during the morning period for a total of about 2,000 people in the general assemblies, and in addition to that, a boys' club meeting in the afternoon. So we are able to reach in excess of about 2,500 of the young people with that mission as well as the basic women's group and it was very, very well put on and I want to compliment you and compliment Major Fullerton.

Senator CURTIS. I am thinking in terms of films that tell the story of NASA developments such as Dr. Paine has told this morning.

ROLE OF NASA EXHIBITS

Senator CANNON. This film covered one particular phase of the program but the narration did cover a lot of the side benefits, the things that you have been talking about here.

Now, in your statement you mentioned the number of people who see NASA exhibits every year and you mention very briefly the fact that you expect 15 million people will view the U.S. space exhibit at Osaka in Japan.

Would you describe more fully the role that NASA exhibits have played in various international exhibits that the United States participates in around the world?

Dr. PAINE. Yes; I will be glad to give you a more complete description of that for the record, Mr. Chairman, but briefly we had an exhibit at the Paris air show last year which was located adjacent to the Soviet Union exhibit, and I think in many ways was indeed the hit of this Paris air show. It came, of course, at a time when there was great interest in the first lunar landing and by all odds was considered the outstanding exhibit. Our exhibits extended all the way from the lunar rock which was exhibited in Moscow to the Japanese Osaka exhibit. In addition, we make exhibits available widely within the United States, both moon rocks and educational exhibits of various sorts.

In addition to that we are putting the Apollo 11 space capsule on a trailer truck and will be moving it through the various State capitals of the Nation during 1970 so that everyone can have a chance to look at this and to see some of the NASA story exhibited alongside this space capsule. So this exhibit program is a program that, I think, doesn't perhaps reach as many people as, let us say, a television show but I think it has a more lasting impact. They have more of a thoughtful opportunity to see parts of the exhibit that interest them the most and learn from it, so we think this a very important program.

Senator CANNON. You haven't lost any more of the moon rocks lately?

Dr. PAINE. No, sir. We have sent out another letter to the people who received samples for analysis waving some rather heavy cudgels in their direction to be more careful.

(The material submitted for the record follows:)

NASA gives extensive support to United States' participation in various foreign exhibits by supplying exhibit materials through the responsible U.S. government agencies. Normally, primary responsibility rests with the United States Information Agency or the Department of Commerce.

In addition to NASA support for official government exhibitors, NASA's historical artifacts are displayed abroad by the Smithsonian Institution. Under an agreement with NASA, artifacts of the space program are turned over to the Smithsonian when they are no longer required for NASA's programs.

Foreign exhibits supported by NASA from 1968 to 1970 include the following:

Jodrell Bank, University of Manchester, England 1968 (2 year loan). APT receiver (same as exhibited at UN Conference in Vienna).

Manitoba Museum of Man & Nature, Winnepeg, Manitoba—This is a long-term recurring exhibit that started in April 1968. ⅓ scale Mercury; ⅓ scale Gemini; Apollo Programs exhibit.

Foreign Lunar Sample Exhibits 1969–1970. Six lunar samples were made available to USIA in 1969 for display at major foreign capitals.

America Weeks Promotion-Isetan, Tokyo, Japan May 1968. Gemini spacecraft, Spacesuit, Space foods display.

International Society of Photogrammetry, Lausanne, Switzerland, July 8–20, 1968. Lunar Orbiter and Surveyor photos, Mapping products, Mosaic of Apollo zone, Gemini photos.

Wing on America Week—Space Exhibit, Hong Kong, August 1968. Gemini full-scale model.

UN Conference on Peaceful Uses of Outer Space, Vienna, Austria, August 14–27, 1968. APT receiver, Photo mosaic of cloud cover, Spacesuit.

Mexico Olympics, Mexico, October 1968. Apollo spacecraft, The Challenge of Space Exhibit.

Singapore Sesquicentennial Celebration, Singapore, April 1—December 31, 1969. Spacesuit; Scale model of lunar module, Apollo display.

Paris Air Show, Paris, France, May 29–June 8, 1969. Apollo 8 spacecraft, F–1 and J–2 engines (NASA participates in each Air Show held every other year.)

British Association for the Advancement of Science, London, England, September 3–10, 1969.

Royal Dublin Society Science Exhibition, Dublin, Ireland, October 21–25, 1969. ⅓ scale model of Apollo spacecraft, 1/96 scale model Saturn C–5, 1/13 scale model Lunar Module, ¼ scale model TIROS Weather Satellite.

Expo '70, Osaka, Japan, 1970. For Time Capsule: Color transparencies, monochrome photos and documentation of mission to Moon and Mars. Sample of beta cloth; For Space Exhibit in U.S. Pavilion: Numerous models and artifacts, including lunar sample returned on Apollo 12 mission; Apollo 8 command module, and a large selection of Apollo 11 artifacts.

Department of Civil Aviation, Melbourne, Australia, 1970. The Challenge of Space Exhibit.

NEW OFFICE TO UTILIZE SPACE KNOW-HOW FOR SOLVING EARTH PROBLEMS

Senator CANNON. In your statement you refer to the necessity of applying the lesson of our space achievements to other national problems. In this connection it was recently announced that the Jet Propulsion Laboratory was establishing a new Civil System Project Office which would attempt to utilize space know-how for solving problems on earth.

Now, is funding for this office included within the contract between NASA and JPL?

Dr. PAINE. Yes. We have been encouraging them to set up a more effective mechanism at the Jet Propulsion Laboratory to find ways of applying the kinds of things that they are doing there in civil areas, and they have worked with law enforcement agencies, school systems, and the Department of Transportation. They have worked with the National Institutes of Health and the example which I cited of X-ray enhancement by using the Mariner-Mars enhancement techniques is an example of the work that is done there.

Senator CANNON. Is this approach one which NASA might utilize at some of its centers?

Dr. PAINE. Yes, we have in fact within our Office of Advanced Research and Technology a Special Projects Office. It has some 12 people and can analyze problems in depth and determine whether the information and capabilities we have within NASA are useful in solving the real problem in a particular area.

NASA ASSISTANCE ON PUBLIC PROBLEMS

Senator CANNON. Is NASA using any other methods to bring its technological capabilities to bear on such problems as public safety, urban land uses, transportation, and so on?

Dr. PAINE. Well, I think, Mr. Chairman, it would only be fair to say that NASA's assistance in this area is a rather passive assistance. There are, of course, other agencies of Government who have the primary responsibility in this area and our assistance normally would take the form of working with them and through them.

In the example I cited of the grooved highway, when the grooved runway proved so successful, we then contacted the Federal highway people and through them were able to move out both to Federal and State highway agencies to get this innovation into place.

Normally we respond to requests from other people or if we see an opportunity in our work to assist them, we call this to their attention and then work through them.

Senator CANNON. Senator Smith.

ASKS PLANS FOR PRESENTING SPACE BENEFITS TO PUBLIC

Senator SMITH of Maine. Thank you, Mr. Chairman.

Thank you, Dr. Paine, for a very comprehensive statement. I find it very interesting and I am sure all of those in attendance at the hearing this morning find it so.

I do agree, however, with the chairman, that we are not getting the actual benefits across to the public. This may be a beginning. I thought from our conversation at the previous hearing when we discussed this matter that you hoped to have a plan to present to us as to how you are going to get all of these accomplishements and benefits out to the public. I note you say in your statement that you think your agency has done an unmatched job of public education in bringing the facts of our highly technical space program to the general public. I think you have with regard to technical facts. But it is not the technical facts that we were talking about the other morning. It was the practical benefits which the layman can understand that will help us get across to the public and to the Senate the need for this program.

You apparently have not come up with such a program.

Dr. PAINE. Well, Senator Smith, we are indeed taking this on as a very high priority item. I don't have a new program to report to you this morning. The very fact that this committee has requested these hearings has caused us to reexamine the worth of our program and to reexamine the degree in which we are effectively telling this story. And although I did say and I believe that we have done a fine job in getting this highly technical message across to the people as to what is going on in the space program, at the same time I agree completely with you that the story of the benefits from space to the man in the street and to the public and to the Nation is the hardest part of our entire communication problem. It is the part that very definitely should be receiving now new emphasis on our part.

I am not satisfied with that part any more than you are. It is a very difficult story to tell and we certainly must find better ways to do it.

Senator SMITH of Maine. Well, if you don't, we won't be able to continue to sell the program to the Senate and to the Congress and that to me is very essential if this great program is to continue in the future.

Mr. Chairman, I have questions but I will delay until a little later.

Senator CANNON. Very well. Senator Holland?

FIFTY NATIONS COOPERATE IN ESRO PROGRAM

Senator HOLLAND. Thank you, Mr. Chairman.

I want to compliment Dr. Paine very warmly. I think that this statement should be printed in book form. I hope the Senate committee will ask for the funds to make available a print for every school and for every public library and for general distribution beyond that because I think there is much in this statement which is needed to be circulated

throughout the country to give information on the value, the very great value of the space program.

Now, Doctor, if I might make three suggestions.

First, you state that in the ESRO program the information is distributed through 50 nations who are mutually cooperating. I think it would be well to give the names of those nations through an annotation.

Second, as a matter of information to myself, does the Soviet Union participate in that distribution of information through ESRO or otherwise?

Dr. PAINE. No. They are not a member of that.

(The information submitted for the record follows:)

The 53 nations represented in NASA's international information exchange program, together with the number of participating organizations in each country, are listed below.

Although the NASA exchange agreement with the European Space Research Organization (ESRO) is a unique element in the NASA exchange program—because of the advanced techniques upon which it relies—it is by no means the only one, nor does it have any governing effect upon the other organizations participating in the NASA international information program. Organizations in the ten ESRO member nations—identified by asterisks in Attachment A—may contribute and receive information through ESRO, for more effective processing, but their individual exchange relationships with NASA are bilateral and direct, as are those in all other countries.

Argentina	7	Italy *	17
Australia	33	Japan	30
Austria	7	Kenya	2
Belgium *	8	Korea	2
Bolivia	1	Lebanon	2
Brazil	11	Malagasy Republic	1
Canada	28	Mexico	7
Ceylon	1	Netherlands *	19
Chile	4	New Zealand	5
China	4	Nigeria	2
Colombia	3	Norway	6
Czechoslovakia	2	Pakistan	4
Denmark *	9	Peru	3
Ecuador	1	Philippines	5
Ethiopia	1	Poland	3
Finland	5	Portugal	5
France *	26	Roumania	2
Germany *	32	South Africa	11
Ghana	2	Spain *	10
Great Britain *	59	Sweden *	13
Greece	7	Switzerland *	10
Iceland	1	Thailand	2
India	20	Turkey	4
Indonesia	2	UAR	2
Iran	3	USSR	2
Ireland	3	Vatican	1
Israel	10		

*Member of the European Space Research Organization.

Senator HOLLAND. Do they participate otherwise in the distribution of information obtained by them or obtained by us which is sent through their bloc of nations?

Dr. PAINE. Yes. We do have cooperative programs with the Soviet Union in several fields. One of these is in the field of weather satellites where we routinely exchange with the Soviet Union our cloud cover

pictures and their cloud cover pictures to help us put together a better global view of the world's weather.

Also in the field of the biological support for manned space flight we and the Soviets at the present time are working on a joint volume with both Soviet and American authors and editors so that we will have the best possible information in this area.

These are two examples of information exchange with the Soviets that have proved valuable to us.

DEGREE OF COOPERATION BETWEEN UNITED STATES-RUSSIA

Senator HOLLAND. Mr. Chairman, I think it would be well to have by way of annotation or otherwise a full statement of the cooperative efforts between our country and our principal rival who should be our principal cooperator because I think there would be great interest in that.

Senator CANNON. Senator Holland, we just recently concluded a hearing on that aspect and it is in the process of being printed now. Are there any additions, Dr. Paine, that would be required to bring that up to date?

Dr. PAINE. No, Mr. Chairman. I think that is a rather complete account and perhaps that really would be the best statement we could make at this time.

Senator HOLLAND. Well, Mr. Chairman, I don't mean to have anything so voluminous as that but to have a statement which will appear as part of this record, part of this statement, showing, first, what are the 50 nations that cooperate through ESRO, and second, what is the degree of cooperation that goes on between ourselves and the Soviet Union, because I think that will be a necessary question that would be asked by people who see the limitations under the ESRO exchange.

Dr. PAINE. Mr. Chairman, I think we could probably usefully furnish a summary of this and that would supplement, not duplicate, some of the previous testimony.

Senator CANNON. Very well. If you will submit that.

(The material submitted for the record follows:)

During the hearing before the Senate Committee on the Aeronautical and Space Sciences on March 11, 1970 Dr. Paine made the following comment on cooperation with the Soviet Union.

> My final subject is cooperation with the Soviet Union. In accordance with the express views of four Presidents and many members of the Congress, NASA has throughout its history sought to engage the Soviet Union in cooperative space ventures. Bilateral agreements for four projects in satellite meteorology, communications, geomagnetic surveying, and space biology and medicine resulted from the Dryden-Blagonravov talks of 1962–65. These agreements provided for coordinated efforts rather than integrated projects. Speaking frankly, the progress under these limited agreements has been disappointing. Nevertheless, I have, over the past several months, written a new series of letters to President Keldysh and Academician Blagonravov of the Soviet Academy of Sciences inviting new initiatives in space cooperation. These letters invite proposals by Soviet scientists for experiments on our spacecraft, welcome their use of the laser reflector left on the Moon by the Apollo 11 astronauts, invite Soviet participation in the analysis of lunar surface material, solicit Soviet attendance at the conference on the Viking Mars mission, offer to discuss coordination of our respective planetary programs, and reiterate our readiness to meet to consider any possibilities for cooperation between us.

President Keldysh has recently replied, agreeing that Soviet-American cooperation in space "bears a limited character at the present time and there is need for its further development." He has accepted my suggestion for a meeting on this question, but deferred further discussion of the time and place for "three or four months" (from December 12, 1969). He declined our specific invitation of Soviet proposals for experiments aboard NASA planetary probes, advocating instead a relationship in which NASA and the Soviet Academy would coordinate "planetary goals" and "exchange results" of unmanned planetary investigations. We will follow up on his suggestions.

We cannot yet know whether these new initiatives will lead to more fruitful discussions and relationships between the U.S. and the Soviet Union in space. The history of our efforts in this regard suggests that we must be patient and not expect early results. I have attached for the record a statement reviewing this history in detail. However, the future could be more promising and we shall continue to press vigorously with Soviet representatives for new cooperative relationships of value to both sides.

The statement reviewing the history of US/USSR Cooperation in Space to which Dr. Paine referred is reproduced below:

US/USSR Cooperation in Space Research

US efforts to cooperate with the Soviet Union in space research go back to the first planning of space projects in 1955 for the International Geophysical Year. In a long series of international meetings, US scientists and those of other nations sought to develop conventions for wide exchange of space data. Soviet scientists consistently opposed obligations of a specific and extensive character. As a consequence, agreements for exchange were held to a minimal or token level. The Soviet side has not fully complied even with these. Further unsuccessful efforts to establish a basis for cooperation were undertaken by the NASA Deputy Administrator in November 1959 during a meeting of the American Rocket Society in Washington, D.C. At that time, Soviet scientists stated that it would be necessary to proceed step-by-step, but they were unwilling to identify a possible first step. Also in 1959 NASA Administrator T. Keith Glennan offered US assistance in tracking Soviet manned flights, but the offer was never taken up.

Although efforts to interest the Soviets in cooperation continued through a variety of channels, there was no progress until the exchange of correspondence between President Kennedy and Chairman Khrushchev after the successful flight of John Glenn in February 1962. In his message of congratulations Mr. Khrushchev repeated the widespread view that it would be a fine thing if the two nations could pool their efforts in space. The President turned this general expression to account by making highly specific proposals for such cooperation and suggesting that negotiators be designated. The resulting talks between Dr. Hugh L. Dryden and Academician Anatoly A. Blagonravov produced the three-part bilateral space agreement of June 1962. The first part provided for coordinated launchings by the two countries of experimental meteorological satellites, for the exchange of resulting data over a Washington-Moscow channel, and for the exchange of conventional meteorological data prior to, and on a secondary basis during, the exchange of satellite data. The second part provided for the launching by each country of an Earth satellite equipped with absolute magnetometers and the subsequent exchange of data in order to arrive at a map of the Earth's magnetic field. The third part provided for joint communications experiments by means of the US passive satellite Echo II. The Dryden-Blagonravov talks also led to a second agreement of November 1965 for the preparation and publication of a joint US/USSR review of space biology and medicine. These agreements call for coordination of independent efforts rather than a cooperative integration of effort but represent the best that could be achieved.

Soviet performance in even these limited projects has been disappointing:

(1) Meteorology

Coordinated launchings of experimental, then operational, meteorological satellites, establishment of channels for the exchange of data thus obtained, plus the exchange of conventional meteorological data on a secondary basis.

Status.—The communications channels were established between Washington and Moscow in October 1964 on a shared-cost basis under which each party pays $28,000 every other month. Scheduled two-way transmissions of *conventional* weather data are made throughout the day. Exchange of *satellite* data began on an experimental basis in September 1966 and continued for some weeks. Soviet transmissions resumed on March 2, 1967. Although they have continued since then except for some intervals, Soviet data has not been operationally useful to us, and it has not been possible to move on to the second stage of the agreement, which calls for the coordinated launchings by the two nations of a system of operational weather satellites. Technical discussions in Moscow in July 1968 have brought some improvement in the quality of Soviet data received in Washington, but further direct attention is necessary to assure data of quality and timeliness adequate for operational use. The Soviets have purchased high-speed data transmitting equipment for use on the link. The equipment is of U.S. manufacture and is identical with that being installed at the Washington terminus.

(*2*) *Magnetic field mapping*

Launching by each country of an earth satellite equipped with absolute magnetometers and the subsequent exchange of satellite and ground-based data.

Status.—The Soviets have provided observations from COSMOS–49. They have received a full description of OGO–2 data, but they have not specified which of this data they wish to receive. Ground-based data have been exchanged, but the exchange has not been completely successful as to regularity, quantity, locations, or format.

(*3*) *Communications*

Cooperative communications experiments by means of the US passive satellite Echo II using the Jodrell Bank and Zemenki facilities.

Status.—These experiments were completed in February 1964. In the event, the Soviets received only, declining to transmit, but did provide reasonable data relating to their radio receptions via Echo II. Technical difficulties (partly at Jodrell Bank) limited the experimental results.

(*4*) *Space biology and medicine*

Preparation and publication of a joint review of space biology and medicine.

Status.—A joint editorial board has been selected and an outline for the chapters of the review has been agreed. The US side is now engaged in having "compilers" put together the basic materials. For almost two years, the Soviet side failed to reply to correspondence. In March 1969 they orally agreed to (1) identify Soviet compilers, (2) confirm Soviet agreement on the outline for the work, and (3) *set ad referendum* a new schedule for the project which called for exchange of materials for the first volume of the joint work in May 1969 and selection of authors for that volume in July 1969. We confirmed this agreement on April 10, 1969. The June 18 Soviet letter of confirmation deferred the first exchange to November–December 1969. The first exchange began in late January 1970.

GENERAL

We have made repeated efforts to persuade the Soviets to enter new projects, but our initiatives have not been accepted. The joint review of space medicine is the only Soviet proposal which has been made and not subsequently withdrawn. A partial chronology of US initiatives (*which does not include numerous actions taken to implement projects already agreed*) follows:

December 7, 1959.—NASA Administrator Glennan offered US assistance in tracking Soviet manned flights. The Soviets replied that they would be in touch if the need arose.

March 7, 1962.—President Kennedy proposed an exchange of tracking and data acquisition stations. The Soviets did not accept.

September 20, 1963.—President Kennedy suggested in a speech to the UN General Assembly that the US and the USSR explore the possibility of joint exploration of the moon. President Johnson later reaffirmed this offer. There has been no official Soviet response.

December 8, 1964.—NASA proposed an exchange of visits by NASA and Soviet teams to deep space tracking and data acquisition facilities. The Soviets replied on August 13, 1965 that such visits were not then possible.

May 3, 1965.—NASA suggested US/USSR communications tests via the Soviet Molniya I. There was no Soviet response.

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August 25, 1965.—At the request of President Johnson, Administrator Webb invited the Soviet Academy of Sciences to send a high-level representative to the launching of Gemini VI. At the same time, the President said that "we will continue to hold out to all nations including the Soviet Union the hand of cooperation in the exciting years of space exploration which lie ahead for all of us." The Soviets did not accept this invitation.

November 16, 1965.—NASA inquired about the possibility of US/USSR communications tests via Molniya I. On January 23, 1966 the Soviets replied that it was not possible to consider joint experiments "in the present conditions."

January 6, 1966.—Administrator Webb asked Academician Blagonravov, Chairman of the Soviet Academy's Commission on the Exploration and Use of Outer Space, for a description of experiments on Soviet Venus probes then in flight in order that NASA plans for Venus probes might emphasize experiments which could complement rather than duplicate Soviet work. Blagonravov replied informally that he did not have authority to describe the experiments.

March 24 and May 23, 1966.—Administrator Webb suggested to Academician Blagonravov that the Soviets propose subjects for discussion with a view to extending cooperation between NASA and the Soviet Academy. Blagonravov replied informally that the Soviets were not ready for further cooperation.

September 22, 1966.—Ambassador Goldberg, speaking in the UN General Assembly, said that if the USSR desired tracking coverage from US territory, we were prepared to discuss with the Soviets the technical and other requirements involved "with a view to reaching some mutually beneficial agreement."

November 11, 1966.—Soviet mission to United Nations declined invitation to participate in UN Outer Space Committee visit to Cape Kennedy to witness launching of Gemini 12.

March 27, 1967.—President Seitz of the National Academy of Sciences proposed to President Keldysh of the Academy of Sciences of the USSR provide the U.S. with some results of the Luna 13 soil meter experiment in advance of Soviet normal reporting to the world scientific community in return for comparable data from future flights in the Surveyor series. President Keldysh replied four months later on July 28, forwarding data which had already been reported at the International Committee on Space Research (COSPAR) meeting in London.

March 27–31, 1967.—Dr. Kistiakowsky, during the visit of a National Academy of Sciences delegation to Moscow, suggested small US/USSR meetings to consider such topics as cooperation in weather prediction, lunar and planetary research, and orbiting telescopes. At the same time, Dr. Brown proposed that representatives of the two academies consider joint space efforts in basic science, excluding rocketry. The Soviets have not replied to these proposals.

April 4, 1967.—Administrator Webb said in his statement on the death of Cosmonaut Komarov that NASA wished to make every realistic effort to cooperate with the Soviet Union. The Soviets have not responded.

June 2, 1967.—Administrator Webb proposed to Academician Blagonravov that they meet in July at the time of the COSPAR meeting in London to review progress in the exchange of weather data as required every six months under bilateral agreements. Blagonravov replied on July 3 that he had been unable to arrange for the presence of the necessary Soviet experts. The required semi-annual meetings have not been held since October 1965.

October 10, 1967.—President Johnson, speaking on the occasion of the entry-into-force of the U.N. Outer Space Treaty, listed previous U.S. offers of cooperation and said "We again renew these offers today. They are only the beginnings of what should be a long, cooperative endeavor in exploring the heavens together."

October 18, 1967.—President Seitz of the National Academy of Sciences, in a telegram congratulating Academician Keldysh on the success of Venus 4, spoke of the need to further full and prompt exchange of data on planetary exploration. Keldysh's telegram of acknowledgement made no reference to data exchange.

December 19, 1967.—President Seitz of the National Academy wrote to Academician Keldysh proposing a small working meeting between the Soviet Venera IV experimenters and the American Mariner V experimenters to compare results of the two Venus probes and to assist each other in understanding the significance of the measurements. Keldysh replied in a letter of January 24, 1968 that he would be sending proposals on this matter shortly. The proposals never came, and there has been no further Soviet response.

April 30, 1969.—Administrator Paine forwarded Academician Blagonravov a copy of the NASA publication, *Opportunities for Participation in Space Flight*

Investigations, and assured him that proposals by Soviet scientists would be welcomed.

May 29, 1969.—Administrator Paine invited Academician Blagonravov to attend the Apollo 11 launching and to discuss informally mutual interests in cooperative space projects. Blagonravov wired that he could not be present.

August 21, 1969.—Dr. Paine invited Academician Keldysh to send Soviet scientists to a September 11–12 briefing at NASA Headquarters for investigators who may wish to propose experiments for the 1973 Viking missions to Mars. Dr. Paine suggested that this meeting serve as an opportunity for a discussion of planetary exploration plans which could contribute to coordinated efforts beneficial to both countries. The letter was not delivered until September 3, and Keldysh pleaded insufficient time to arrange attendance by Soviet scientists. At the same time, he asked for copies of materials to be distributed at the meeting in order that Soviet scientists might develop proposals and suggested the possibility of discussions at a later meeting.

September 15, 1969.—Dr. Paine forwarded the Viking materials requested by Keldysh and offered to provide a separate briefing for Soviet scientists.

September 18, 1969.—Dr. Humphreys, NASA Director of Space Medicine, asked Professor Gazenko of the Soviet Commission for the Exploration and Use of Space to make specific proposals for an exchange, previously discussed during informal conversations, of young biomedical scientists to work on predetermined projects in preselcted laboratories or institutions in the US and the USSR. Gazenko's undated reply, received in NASA December 9, stated that he needed more time for consultations before speaking to the substance of the Humphreys letter.

October 3, 1969.—Dr. Paine assured Academician Keldysh that we would welcome proposals from Soviet scientists for the analysis of lunar samples.

October 10, 1969.—Dr. Paine forwarded Academician Keldysh copies of the Space Task Group Report to the Space Task Group and suggested discussions looking toward the US and the USSR undertaking major complementary tasks to the benefit of both countries. On December 12 Keldysh acknowledged the STG materials on long-range US space planning. He agreed that Soviet-American cooperation in space "bears a limited character at the present time and that there is a need for its further development." He accepted Dr. Paine's suggestion that they meet on this question but deferred further discussion of the time and place for "three or four months." He declined Dr. Paine's specific invitation of proposals for Soviet experiments aboard NASA planetary probes, advocating instead a relationship in which NASA and the Soviet Academy would coordinate "planetary goals" and "exchange results" of unmanned planetary investigations.

December 18, 1969.—Dr. Paine invited Academician Keldysh to send Soviet scientists to the Apollo 11 Lunar Science Conference. They did not respond.

January 29–30, 1970.—Soviet Mission to United Nations declined invitation to join UN Outer Space Committee on visit to Manned Spacecraft Center for briefing on US earth resources survey program.

In March 1958, the US National Academy of Sciences alerted the international scientific community, through the International Council of Scientific Unions (ICSU), to the importance of preventing initial planetary probes from contaminating the planets and thus compromising critical scientific experiments seeking to determine the presence of extraterrestrial life. As a result of this initiative, a series of efforts ensued to develop exchanges and commitments between East and West. The International Committee on Space Research (COSPAR) finally recommended in 1964 that authorities launching deep space probes adopt spacecraft sterilization techniques which would reduce the probability of contamination to specific acceptable levels. The UN Outer Space Treaty of 1967 raised prevention of harmful contamination of the planets to the level of an international obligation. The US has undertaken an extremely costly effort to make sure that its probes do not contaminate the planets and has published in great detail the measures adopted to that end. A COSPAR Consultative Committee on the Potentially Harmful Effects of Space Experiments has repeatedly attempted to elicit similar information from the Soviet side, through meetings, symposia, and correspondence, so that the adequacy of Soviet techniques can be exposed to the judgment of the world scientific community. Over the entire ten-year period of such efforts, the Soviets have been willing to provide little more than generalized assurances that their spacecraft are sterilized. While there is a general consensus that Soviet rocket stages are in fact permitted to impact the planets, no assurances of any kind have been forthcoming regarding their sterilization or diversion from the planets.

It is apparent from our experience that cooperation with the Soviet Union is not limited so much by technical considerations as by political considerations on the Soviet side. Soviet spokesmen have themselves said that political questions preclude more extensive cooperation with the United States. In our experience, the Soviets have limited space cooperation to scientific and theoretical rather than technological and operational matters. They have not been prepared to talk about their plans and to look with us at what might be accomplished. Thus, many intrinsically meritorious proposals for cooperation have little prospect of gaining Soviet acceptance.

The success of our efforts with other nations in space is a measure of the difficulty of cooperating with the Soviet Union. Acting on the injunction in the National Aeronautics and Space Act of 1958 to cooperate with other nations and groups of nations, NASA has joined with scientists of some seventy countries in cooperation which has ranged from ground-based studies with NASA satellites to programs involving the actual flight of satellites designed and built abroad. Twelve foreign scientific satellites have been launched in cooperative international projects involving Canada and ten European countries, two others under reimbursable arrangements, and more than five hundred sounding rockets have been launched in programs involving scientists in nineteen countries. Invitations to American scientists to prepare experiments for flight on NASA satellites are regularly accompanied by parallel invitations to the international scientific community. In this program, seventeen foreign experiments have already flown, four more have been selected for flight, and another thirty-five are under consideration. In addition, we have selected proposals from fifty-five scientists from sixteen other countries for experiments on lunar materials being brought back by returning astronauts.

We regret that the Soviets have not been prepared to move more rapidly and more broadly to cooperate in space. We would welcome meaningful cooperation in projects of mutual interest and have set no arbitrary limits of any kind. We do not propose to stop trying, but it seems apparent that significant cooperation depends upon the Soviet Union effecting very substantial changes in its attitudes.

VALUE OF ADVANCED SPACE WEATHER WARNING

Senator HOLLAND. Now, the third point, I think that one of the most compelling things you have in your statement, and the most appealing to people generally, will be your statement about the saving of life at the time of the Camille catastrophe, and I am very sure that many thousands of lives were saved. I suggest that as an example of what might have happened in that whole coastal area with the whole gulf offshore, much of which was quite shallow as it approached the gulf coast, that you include somewhere a notation showing that in 1926, with a storm coming from the direction of the winds coming from the east, there were 300 lives lost in the comparatively thinly populated west shore of Lake Okeechobee in Florida. Again in 1928 with the winds coming from the west, and with a thinly but more fully populated shore along the east and southeast side of Lake Okeechobee, there were 2,200 lives lost. These two disasters alone, not to mention others, indicate what might have happened in that very much more heavily populated gulf coast area, if there had not been the advance warning given.

Now, one more thing I want to suggest and I suggest this because I am a layman and I have noted three or four technical terms used here which I can't understand, like angstroms and——

Dr. PAINE. They do creep in.

Senator HOLLAND. Do you have an annotation showing the meaning of those terms so that the school child or the school professor reading this document can understand what you are talking about?

Dr. PAINE. I do try to keep these out, Senator Holland. They will creep in in the later hours of the night and I will see to it that an

asterisk is put by each one and an explanation. You are absolutely right.

Senator HOLLAND. Well, now, the members of this committee are not school professors but we have listened to a good bit of the development of this program through the years and I do think we may have a greater understanding of the terminology which you employ than many people, even than many school professors, and I do think that there should be annotations when you use a term of that kind which you did use twice in this article and of which I haven't the slightest idea as to what its meaning might be and I doubt if there is anybody on this committee that does. I think that to have a fuller understanding of this very, very fine article which you have submitted which shows so clearly the immense value that has come to our country from the space program, that there should be an explanation of those highly technical terms which occasionally you have allowed yourself to use, as you say, in the dark of the night when you were exhausted.

I hope you will have a full statement of just what those terms mean.

Thank you very much, Mr. Chairman.

Dr. PAINE. I will take care of that, Senator Holland.

An angstrom unit is about half the diameter of an atom. It is a unit of length. I will see to it that this is put in.

(See footnote 4, p. 16.)

DISTRIBUTION OF HEARING

Senator CANNON. Senator Curtis?

Senator CURTIS. Mr. Chairman, I want to commend the distinguished Administrator for his statement. I think it is splendid. I think it is very helpful. I feel we ought to follow through on Senator Holland's suggestion that this be published in great quantities and that it is not done by NASA, but must be done by the Senate. I think the record ought to show that our distinguished acting chairman is a member of the Committee on Rules and Administration which handles all printing. [Laughter.]

And the junior Senator from Nebraska is the ranking minority member there, so there will be some friends in court in case it becomes a reality and follows that route.

Senator HOLLAND. Will the Senator yield there?

Senator CURTIS. Yes.

Senator HOLLAND. Every Senator, regardless of party, has the privilege of distributing the agricultural yearbooks and they are greately sought after, and heavily read, and very actively used by the people that are primarily interested in agriculture. I suggest—and this, of course, is completely a bipartisan suggestion—that these books be made available for such distribution because I think there will be some requests coming in to us that wouldn't go to you people because you are regarded by the average public as the epitome of great scientific attainment and many individual citizens hesitate to approach your throne, whereas they are perfectly willing to approach their Senators, who can send out many thousands of such books to areas where they will do good.

I thank the Senator for yielding on this point.

SPACE PROGRAM FOR BENEFIT OF MAN ON EARTH

Senator CURTIS. Mr. Administrator, I especially appreciate your material this morning for the help that it will be to the general public. Personally I have no problem in my own mind, in my own official position, in wholeheartedly supporting the space program. I yield to no person in my concern for the ever-expanding Federal Government and the great expense. I think that unless something is done about it, it will be our downfall. There are some things that can only be handled by the Federal Government and the space program is one of them and to my mind it is an erroneous cliche or suggestion that space is not for man on earth and why not spend this money for problems on the earth when there are so many great needs here.

In my opinion the entire space program is for the benefit of man on earth. There is no one else benefitting. And that benefit is very great. It isn't a benefit to space or the moonbeams or is anyone else going to reap the benefits or have their environment changed.

I think back to the time of Ben Franklin flying his kite, making the discovery about electricity. It was many, many years after Franklin's experiment before electricity affected the lives of people. Why have the benefits from space moved so much more rapidly?

Dr. PAINE. Senator Curtis, that is a very thoughtful question and nobody really knows the answer. There have been a number of studies made of the speed with which new scientific facts appear as technological advances and the data are very conflicting. I think you can make a case that the way in which we are handling the transfer of scientific and technical information today does facilitate the earlier use by mankind of new science and new technology. You can make a case that the way in which NASA has organized to handle the work of exploring space not within a Government institution but with only about 10 percent in the Government with a large component in U.S. industry and U.S. academic research and university campuses, has facilitated the kind of information exchange that makes it possible to speed up the process. You can postulate that in the past the great challenge of war and of continental frontier expansion that I mentioned in my testimony has greatly speeded up such advances but I think to be honest we have to admit that we don't fully understand the process. There seem to be times of great outpouring of national energy and creativity and there seem to be other times, for example, during the depression in this country, when we don't make advances on any front, artistically, technologically, and socially.

These things really aren't very well understood. But as I tried to indicate in my testimony, I do believe on an intuitive basis and I do believe we can show some facts to indicate that American decision to take up the challenge of space in 1958 has indeed sparked a great forward thrust in science and technology. We can even talk about social impact when many of our new centers were located in parts of the country which did not have advanced science and technology. I think this decision has indeed speeded up the process whereby we can bring things right down to the man in the street and make it useful to him in a shorter period of time.

COMMENTS ON NASA ORGANIZATION

Senator CURTIS. Well, I have no quarrel with what you said but I think there is a far more apparent significant reason for this miraculous application of scientific knowledge being translated from space to thousands of products and processes that affect the household already. And that is the fact that the NASA organization—I am not speaking of individuals now, I am speaking of the basic concept of it which the Congress may play some part in it, I don't as an individual—has perfected a working arrangement not only between the NASA agency and our institutions of scientific learning. That part has been done before. But now with industry as well. The fact that NASA has not been an agency where the Government does work in-house but rather contracts with industry to get a better job done. As a result, everything that is going on from day to day is right there for industry to have its imagination challenged. Not that they violate government patent rules or anything else, but they were just in it. Consequently their application for competitive reasons was instantaneous. I think that has had a lot to do with it.

Dr. PAINE. I would agree with you, Senator Curtis. I think the fact that we kept within NASA enough highly qualified people and enough very challenging work in our own laboratories so that we were able to evaluate the relative proposals of industry and supervise the work in a knowledgeable way also had a great deal to do with this.

Now, I think there is one other point which I mentioned briefly in my testimony but which I would like to mention again, and that is that one of the impressive things about the space age in the last 12 years that really puts the lie to those who claim that we have to radically restructure our society today is the fact that NASA was able to work within the great flexibility of existing U.S. institutions. We didn't change the civil service laws in order for NASA to go to the moon. We didn't change the fundamental structure of our universities, or of our free enterprise system. All of this was done within American institutions and those who say today that in order to make America move forward to the future we have to tear things down I think need only look at the successes which NASA has had working within the system as a vivid demonstration that this country has the flexibility within its institutions to accomplish anything which the people of this Nation decide they will accomplish.

Senator CURTIS. I expect the basic operation of NASA is a result of the planning of many individuals but I think it has been very successful and I would hope that NASA would fight to the bitter end to continue that system and not permit, just because space has now become attractive and successful, that the efforts be proliferated and extended to a multiplicity of Government agencies and departments. That would be a tragic mistake.

VALUE OF SPACE PROGRAMS

Incidentally, I am not too disturbed about individuals questioning the value of the space program. A brilliant young lawyer here working for the Government who is an attorney for the Committee on Rules and Administration, Mr. Burkett Van Kirk, comes from my State. His grandfather was the distinguished U.S. Senator, E. J.

Burkett, from Nebraska, who preceded me in the House of Representatives for the First District many years before, and then served in the Senate.

At the time the airplane was being developed, he journeyed from Washington to watch a demonstration of the airplane as a member of the Military Affairs Committee, came back and signed a report and said it was a very interesting experience but it would have no military application. And it has been the source of considerable amusement since then.

I might suggest this, in reference to getting the story of NASA on the level where everybody would have an interest and understand it, that some document be prepared that would have as its starting point an inventory of products, the development of which have been effected by the NASA program, even though others may have had some part in it. It is true the effect on environment, the effect upon management, and so on, has a fascinating story but the average housewife, the individual worker, has a direct interest, for instance, in inflammable materials.

I heard the other day that there is some lining that they put in pots and pans so things do not stick—Teflon—that had a relation to the space program. So instead of starting out from the theoretical angle, I think—because this shouldn't be done by one writer, this should be done by all branches and authorities in space programs contributing to it in the first instance. If you started out with a list of products that people know about, some of which they have in their homes, others of which they have seen advertised, take off from there, then in addition to all this other fine material you have, a very good selling job can be done.

TELEVISION EXPERIMENT WITH INDIA

I might ask one question about material in your statement where you state that "a future ATS will broadcast educational television directly into 5,000 Indian villages."

Are you referring to the broadcast direct from the satellite to the individual viewers receiving it without going through a broadcast station which is the way it is done now?

Dr. PAINE. Yes. This is an experiment which we are planning for an ATS satellite, not yet launched, which after a number of NASA experiments have been done with it, we plan to move into the stationary position over a location where it will be available to the Government of India who will transmit television up to the satellite of an educational nature. The satellite will then directly broadcast that signal down to individual antennas on each augmented community television set in the 5,000 villages. NASA's contribution here is only to make available on a loan basis the satellite broadcast time to the Indian Government which is in control of all of the program material.

They are now doing experiments with a ground based transmitter to Indian villages on an experimental basis testing the degree to which the television broadcast material can help improve conditions in the villages.

For example, in the springtime they broadcast information on how to prepare the soil and how to plant seeds. During the summer it is

how to insure adequate irrigation and to prevent weeds. In the fall it is how to harvest and to protect the crops from deterioration.

It is this kind of direct information to the villagers, many of whom are illiterate, but they can listen to the language and they can see the images on the screen, that the Government of India hopes to be able to use to not only improve conditions in the villages but perhaps even to slow down the process of emigration from the villages into the cities of India which are already so overcrowded.

The initial experiments are being done in which villages which do have television receivers are being compared to those which do not have TV receivers, so that the effect of the various programs can be evaluated before the community broadcasts from orbit which will be several years from now.

Senator CURTIS. Now, I can understand the value of that to developing of backward nations where a locality cannot afford a television broadcasting station. I may say that it has our broadcasters in the United States scared to death. The broadcast stations are sort of like the hometown paper. Its broadcast can be geared to local needs of immediate interest to the area. Local business concerns can advertise.

If we go into a system of broadcasting directly from the satellite to the receiver, it will have a cultural effect. There will be no longer a local television broadcasting station.

Senator GOLDWATER. Will the Senator yield?

Senator CURTIS. Yes.

Senator GOLDWATER. I think that Dr. Paine said that the material has to be broadcast from earth to the satellite and back. I don't believe that this is a self-contained satellite, that it is——

Senator CURTIS. I understand that. I understand that, but, you see, at the present time our networks, whether they are satellite or otherwise, to get it back to the people, they have to go through the local broadcasting station. If that step is eliminated, it will change something very material here and also have an element of monopoly and bigness in it because the television audience will be so large that only advertisers, unless this is funded as a government subsidy, who sell worldwide would be interested in buying time.

Now, even though something goes through a satellite at the present time, originates in a foreign country or at a network headquarters, if it travels through the local stations even for pauses of spot announcements, and so on, it can still keep many broadcasting stations in business.

I do not want to be misunderstood. I am not opposing progress here. I do think that just as the local newspaper is a part of our culture, so is the local broadcaster. I also think it has a very great element of putting television advertising in the hands of gigantic concerns who would want to sell over a great portion of the globe as contrasted to the merchant on Main Street. I have no specific suggestion at this time but I felt that it should be called to the attention of NASA and this committee because it will have very far-reaching effects. At the same time I can understand that if you could say to great groups of applicants, for instance, that you can have television broadcasting stations, you might have done something for a great number of people.

Mr. Chairman, there are a few other questions that I will take the time after others are finished but I won't take any more time now.

Senator CANNON. Senator Goldwater.

PLANS TO DISTRIBUTE NASA INFORMATION

Senator GOLDWATER. Dr. Paine, I want to join the others of the committee in complimenting you on this very fine and, I would say, overdue statement. I agree with the others that it should be made available.

I was wondering in connection with Senator Smith's—Senator Smith of Maine—I now have to identify the Smiths because there are two of them on this committee—her inquiry about what you are doing relative to plans to disseminate this material.

Have you talked with any of the professional public relations firms in this country on this problem?

Dr. PAINE. Yes, I have, Senator Goldwater, including some very talented people like Dan Seymour who heads the J. Walter Thompson organization in New York, and he has been very generous with the time of himself and staff to give us advice and comments as to how he thinks we should be proceeding to tell our story better. We are attempting to use the views that we get from people like Dr. Seymour and others to do a better job.

In that connection, I have taped some material to be broadcast during the duller hours of the Apollo 13 mission by the CBS people in which I attempt to try to get some of this across. It is, however, as I indicated to Senator Smith of Maine, one of our toughest problems and it is obviously going to be something that we are going to have to continue to work very hard on.

Senator GOLDWATER. Well, I am glad to hear that. I imagine that you could be criticized if you used public funds to hire an organization such as we are talking about, but I think we should explore it because it can be done. I have been in the advertising business and I think it can be done in a very dramatic way that will bring people to appreciate what NASA has. I know to add to your figures, I have shown the material that you have generously given to me or loaned to me to over 10,000 people in Arizona. I think that all Senators should be made aware of the fact that you do have this material, and particularly that the young people just eat it up.

COMMUNICATIONS SATELLITES

In your statement you talk about communications satellites and as I understand it now, these satellites can only reflect frequencies in the gigahertz range. Is that correct?

Dr. PAINE. That is correct. These satellites have their own frequencies allocated to them both by the United States FCC and the Nation that their radiation reaches. This is a part of international Intelsat consortium's responsibilities to see to it that the right frequencies are available.

Senator GOLDWATER. Is it electronically possible to have a satellite that would reflect 20 to 30 megahertz?

Dr. PAINE. Well, in fact, there is a wide variety of frequencies which we can use and I don't recall the specific frequencies we are using

in the Indian community television broadcast. I can furnish that for the record. Perhaps it would be well, if you would like to hear more on this, for Mr. Jaffe to amplify that?

(The material submitted for the record follows:)

The frequency being used for the Indian Experiment is 850 MHz.

Mr. JAFFE. Senator, the frequencies of 20 to 30 megacycles could be broadcast from a satellite but the size of satellite required to make this feasible probably would eliminate the practicality of the situation. Most satellite communications systems rely on the upper frequencies from 700 or 800 megacycles on up for communications purposes of the type we are talking about here.

Senator GOLDWATER. When you talk about size, would it be too small or too large?

Mr. JAFFE. The satellite itself would physically get very large. The amount of power required at these lower frequencies would become very large so the satellite becomes impractical from the economic point of view.

Dr. PAINE. The antenna also would have to grow.

Senator GOLDWATER. Are you continuing studies in these fields?

Mr. JAFFE. Yes, sir, we are. We do continue studies in these fields. As a matter of fact, for scientific purposes, from a standpoint of understanding the ionosphere and the effect of the ionosphere on conventional land based transmission, we do fly satellites in these frequency areas to better understand the ionosphere so that we can predict transmission capabilities.

Dr. Paine asked me to mention the OSCAR satellite which was just flown for the amateur radio community, which was one of the satellites of this type. It did radiate in this area of the spectrum for purposes of better understanding the ionospheric environment and its effect on conventional transmissions at these lower frequencies.

Dr. PAINE. I believe you are probably familiar with the OSCAR satellite.

Senator GOLDWATER. Yes. The reason I am concerned is that these frequencies are particularly susceptible to propagation and on some of the better frequencies particularly around 10 years, we have had 20 years of bad propagation.

So that you won't think it is a selfish reason, because I am a radio operator myself, we do a tremendous amount of worldwide communicating with the military and particularly in bringing the GI closer to home through these frequencies, so I would hope that as you continue your studies of the whole frequency spectrum and give attention on occasion nationally to the megahertz field.

Dr. PAINE. Yes.

SOVIET-AMERICAN SCIENTISTS

Senator GOLDWATER. Now, one other question, and this has been brought up before by Senator Holland. You talk about your central computer located in Darmstadt, Germany, serving scientists through remote terminals in Paris, Brussels, et cetera, and you are putting in additional terminals.

I think that Senator Smith of Maine was the first member of this committee to point out the tremendous value to a better understanding

between the Soviets and ourselves from having the scientific field get into this whole act. I am convinced that the political field is never going to bring it about but I do know that you gentlemen in discussing your scientific problems with the Soviets have no compunction about talking to them. They have none in talking back to you. I found out that at air shows the Russian pilots will talk with us and talk about their programs just as we will talk to them about ours. And I hope that you would go along with the suggestion first made by Senator Smith of Maine that we do everything we can to get our scientific fraternity closer to the Russian scientists. I think this is a chance and probably the only chance we have at the present time.

One other thing, and this again is commenting on a question of the Senator from Florida. You have a heck of a good dictionary with all of these gobbledegook identifications but it is out of print. I got one the other day and I wanted another to send one home to one of my grandchildren who is going to be one of your employees, I hope, someday but there are none around. So could you look into reprinting that? It is a very valuable thing. I can go home and understand what you have been talking about.

Dr. PAINE. I will look into that, Senator Goldwater.

It is hard to keep it up to date. We keep adding acronyms to it.

With respect to our previous comments I might mention that our Deputy Administrator, Dr. George Low, has been invited and will be presenting a paper in Leningrad this spring which describes the Apollo program with ability really I think to accomplish this down to earth transmission between technical people that you were discussing.

Senator GOLDWATER. Thank you. I have no other questions, Mr. Chairman.

FUNDS FOR EARTH RESOURCES PROGRAMS

Senator SMITH of Maine. I have some questions that I will ask to go into the record and be answered for the record in the interest of time.

(Questions submitted by Senator Smith and answers supplied for the record by Dr. Paine are as follows:)

Question 1. How much will you spend in fiscal year 1970 for the Earth Resources Survey Program? How much money is budgeted in fiscal year 1971 for this Program?

Answer. The following funds have been programmed by NASA for the Earth Resources Survey Program for FY 1970 and FY 1971:

	Fiscal year 1970	Fiscal year 1971
ERTS A. & B. spacecraft	$15,000,000	$41,500,000
Aircraft program	11,000,000	11,000,000
Supporting research and technology	9,022,000	9,000,000
Construction of facilities	67,000	2,050,000
Launch vehicle		3,900,000

Question 2. In regard to $2.1 million Construction of Facilities request for Goddard, is this a unique facility or is this only one of many that may be required in regard to processing data from Earth Resources Satellites?

Answer. The Earth Resources Technology Laboratory, planned for Goddard Space Flight Center, is a unique facility required for the control, data processing,

and related activities of the research and development Earth Resources Technology Satellites (ERTS) A&B. Project management of ERTS A&B was assigned to Goddard by the Administrator on January 7, 1969. Control of these satellites and real-time processing of Earth Resources Survey data require close integration of the command and control center and the data processing facility; for this reason, as well as reasons of economy, the data facility is being integrated with the existing control center at Goddard. The facility will provide housing for the real-time processing operation, which is essential to issuance of proper commands to satellite on-board equipment.

The operation of this facility will provide for the timely receipt, processing and distribution of space-acquired Earth Resources Survey data to user agencies for direct application to resource management problems. This, as well as all other key decisions pertaining to this program, has been reviewed and approved by the Earth Resources Survey Program Review Committee, which includes the Department of Interior, Department of Agriculture, Department of Commerce, Navy Department and NASA as members. It is envisioned that this facility will satisfy user requirements for data from approved R&D ERTS satellites, and will provide essential information necessary for the design and operation of later operational Earth Resources Survey programs.

In addition to this data facility, NASA operates a research data facility at the Manned Spacecraft Center, Houston, Texas, which serves a related function for Earth Resources Survey data obtained from our manned space flight program and our aircraft program. We have no plans for construction of additional data facilities.

Senator CANNON. Thank you very much. There will be some questions submitted for the record and you can supply the answers.

Senator Curtis also has some questions he will submit.

(Questions submitted by Senator Curtis and answers supplied for the record by Dr. Paine are as follows:)

EXPORT SALES OF COMPUTERS

Question 1. In your statement you mention that export sales of U.S. computers reached $728 million in 1969, and later you say that the export sales of aircraft and parts rose to $2.9 billion in 1969. Are these two figures independent of one another?

Answer. The two figures are independent of each other to the extent that there is no redundancy of the sales data. Computer sales consist of exports of all types of computer equipment where it is possible to separate such sales. Hence, these exports consist of business and industrial computers plus computer systems for aircraft and missiles. Export sales of aircraft and parts include (1) total sales overseas of complete aircraft and (2) aircraft parts not elsewhere classified, such as electronic equipment and computers. Basically these parts consist of everything other than electronic equipment.

EXPORT SALES OF AEROSPACE INDUSTRIES

Question 2. Do they include all of the export sales of the aerospace industries?

Answer. No, they do not. There are other types of airborne electronic systems not included such as radar, communications and navigation equipment. These belong to a different category of sales which are not separately identifiable. Aircraft and parts data, for example, include all equipment installed as part of a complete aircraft or missile system, but not electronic systems sold separately as spare parts.

U.S. BALANCE OF TRADE

Question 3. How important are these sales to the trade balance of the U.S. and to our balance of payments?

Answer. Total overseas sales of computing equipment and aircraft and parts have increased steadily during the past ten years. Since 1964, total sales have represented a growth of about 4.7 percent of total U.S. exports, from 4.96 in 1964 to 9.66 percent in 1969.

With respect to the U.S. balance of trade, the increase has been substantial. However, one must consider the fact that the U.S. balance has been declining—from $7,083 million in 1964 to $837 million in 1968, and then up slightly to $1,262

million in 1969. Compared with the balance of trade data, total sales of these categories have grown from 18.69 percent of our overall trade balance in 1964 to 380 percent in 1968, the lowest year for the balance, and down somewhat to 290 percent in 1969.

TABLE ON AEROSPACE INDUSTRY SALES

Question 4. Would you please provide for the record a table for the period 1964 through 1969 showing the aerospace industry sales—you might want to break that out into aircraft, computers, etc.—and the trade balance and balance of payments?

Answer. The data requested are provided below:

[Dollars in millions]

	1964	1965	1966	1967	1968	1969
Computing equipment	$217	$223	$295	$433	$486	$728
Aircraft and parts	1,106	1,359	1,404	2,009	2,693	2,936
Total (a)	1,323	1,582	1,699	2,442	3,179	3,664
Total exports (b)	26,650	27,530	30,430	31,622	34,636	37,988
Trade balance (c)	7,083	5,322	3,872	4,141	837	1,262
(a)/(b) percent	4.96	5.75	5.58	7.70	9.18	9.66
(a)/(c) percent	18.69	29.80	43.80	58.80	380.0	290.0

NASA DEVELOPED PAINT MARKETED

Question 5. In Appendix 1 you mention a paint developed by the Goddard Space Flight Center. This product was made available two or three years ago.

Could you tell us how wide an acceptance this paint has received?

Is it being actively marketed? If so, for what uses?

Answer. On January 1, 1970, there were 29 active non-exclusive licenses issued to companies for the purpose of manufacturing the silicate-based inorganic coating developed at Goddard Space Flight Center and announced in NASA Tech Brief 65–10156. Inconsistencies in available raw materials and problems encountered in attempts to repeat precise formulations in bulk lots on a production basis have delayed many of the licensees in their efforts to make their formulations available for sale.

A Wisconsin company, the Wisconsin Protective Coating Corp. in Green Bay, is producing the coating for industrial application. The company reports that it is being applied as a protective coating inside railroad tank cars being used to transport solvents and as a protective coating for the inside of high temperature smoke-stacks.

RETURNS FROM SPACE PROGRAM INVESTMENT

Question 6. The President's annual report on the space program shows that over a period of 15 years and through the end of FY 1970, we will have spent more than $57 billion on all of our space programs for all federal agencies, NASA, DOD, AEC, Commerce, etc. Considering all the things you have told us today, is there any rational way that we can say, in dollars, what the return has been and might be expected to be from that expenditure?

Answer. The objectives of the national space program can be defined as the expansion of human knowledge through space exploration, the development and operation of space systems, the application of space science and technology to terrestrial problems, and the maintenance of the national security. In working toward these objectives, the space program results in the creation of wealth through the advancement and broad dissemination of new scientific knowledge and new technical developments. It is not possible, in light of today's imperfect understanding of the totality of societal interactions, to quantify the increased output that is directly related to the space investments of the past 12 years.

One measure might be the growth in national wealth and productivity: the gross national product has more than doubled since 1959, going from $469 billion then to $960 billion today—an increase of over 100%. In 1947, the productivity index for manufacturing (as shown in the President's 1970 Economic Report) was around 72; twelve years later, it had grown to 98—a 26-point increase. Compare this with the growth to around 145 over the succeeding period to the

present—an increase of 47 points, or nearly double the earlier rate of growth. This is a reflection of technology moving into high gear—and space has been a driver of the advanced technologies. We do not and cannot claim that space alone has created all the new productivity we enjoy today; we can say intuitively it would have been significantly less without the dynamic leverage of a space program.

The nation's economic effort over the past twelve years can be measured as totaling over $8 trillion. Of this, more than $2.4 trillion was real growth over the 1959 level. Approximately 50% of growth in productivity is attributable to the flow of new technical knowledge into the economy. That knowledge comes from research and development investments and 25% of the nation's total R&D was carried out under the space program. The space program is therefore responsible for a major part of the new technology which creates wealth and productivity. This would be one way to estimate conservatively the force for progress exerted by the space program.

The future is far more difficult to predict than the past is to analyze, but as space exploration and applications mature, and as new technologies find ever-increasing uses, I feel that the economic returns we will measure in the second decade will continue to be in large multiples of their cost. This ignores the immeasurables—I can place no dollar value on national security, on a stable international scene, on lives saved, on knowledge gained, on national self-confidence and pride. Yet all these and more are already the fruits of our past investments.

DISTRIBUTION OF NASA FILMS

Question 7. In Appendix 3 of your statement you mentioned that NASA develops and distributes 16 mm sound film. Will you elaborate on the manner in which NASA acquaints schools and organizations with the kinds of films that are developed and how such films can be obtained?

Answer. Distribution of NASA films to schools throughout the United States is based upon procedures worked out cooperatively between NASA Center Educational Officers and state school officials. To facilitate this and its other information programs, NASA has divided the country into regions of several states each, with information responsibility within each region assigned to a major NASA Center.

NASA issues periodically a publication describing all of its educational/informational films. Names of libraries from which schools may borrow films are included. This publication is sent to approximately 50,000 teachers, upon their request.

Schools may borrow a print of any NASA film from the nearest NASA Center film library without charge other than return postage. In 1969, nearly five million elementary and secondary students saw NASA films in their classrooms.

At the time each new film is released, an information sheet on the film is sent to 900 audio-visual director and media center directors who acquire films for school systems. This information is also mailed to 30 educational journals and periodicals which print announcements or reviews available to schools.

Preview prints of new NASA films are sent by request to the Science Teaching Center of the University of Maryland whose staff prepares reviews of all science media for publication in the monthly periodicals of the National Science Teachers Association. Review prints are also provided to other publications upon request.

NASA films are regularly shown at the national conventions of educational, science and audio-visual groups, as a means of introducing the group to a new film. Several NASA films were shown recently at the National Science Teachers Association Convention in Cleveland and at the National Association of School Administrators Convention in Atlantic City. Representatives of NASA's Educational Program participated in, and provided information about films as well as other educational services, at four regional meetings of the National Science Teachers Association, and at meetings of the National Council for Teachers of Mathematics, the American Personnel and Guidance Association, the National Association of Secondary School Principals and the National Aerospace Education Council. Lecturers in the Agency's Space Science Education Project make use of films in their Spacemobile presentations at schools, and in so doing make known the procedures by which schools may obtain and make use of the films. A booklet "NASA Educational Publications" which describes publications available to teachers and students, includes mention of films and suggests that teachers

write for the NASA Film List. During the summers, NASA films are widely used at teacher workshops throughout the country. Last year, films were provided to nearly 400 such workshops.

Prints of NASA films may be purchased by schools and media center libraries for frequent use. The available titles are listed in a catalog published by the new National Audio-visual Center of the National Archives and Records Service, and the price includes only the laboratory cost of the print plus handling and shipping charges. This Center has sold more than 1,450 prints of the NASA film "Eagle Has Landed: The Flight of Apollo 11."

Announcements of new films are also mailed to Headquarters of 53 national organizations including Rotary, Kiwanis, American Legion, etc. The film announcements are usually published as information for program chairmen.

UNIFIED POLICY FOR TECHNOLOGY TRANSFER

Question 8. An article in the March 21 issue of Business Week states that the Administration is "making a fresh attempt to get technology out where the problems are. The result could be the first unified federal policy for technology transfer. Though federal officials will not spellout details yet, such a policy presumably would fuse the separate technology transfer programs of different federal agencies.

". . . it is not yet clear how the new technology transfer setup will mesh with NASA's program and those of other agencies."

Are you able to give us any details about this new proposal, particularly as to how it might affect NASA?

Answer. The Committee on Intergovernmental Science Relations of the Federal Council for Science and Technology is currently preparing a report recommending actions by the Federal government to strengthen science and technology at the state and local levels. Technology transfer of federal research and development results is being given major consideration. NASA is represented on that committee.

The NASA Technology Utilization Program, established in response to the mandate in Section 203(a)(3) of the National Aeronautics and Space Act of 1958, to . . . "provide for the widest practicable and appropriate dissemination of information concerning its activities and the results thereof". It is designed to make available, through experimental technology transfer mechanisms, scientific and technical information generated through the conduct of NASA programs, to other sectors of the national economy, including medicine, education, and industry.

NASA is working closely with the Department of Commerce and the Small Business Administration. We are providing our new technology to other federal mission-oriented agencies such as the National Air Pollution Control Administration, Law Enforcement Assistance Administration, Federal Water Pollution Control Administration, Department of Transportation as well as to a number of public organizations at the state and local levels.

Through the establishment of a Technology Utilization Program NASA has provided leadership within the federal government in the areas of acquisition and transfer of new technology. We expect that the experience and knowledge gained through these experimental programs will impact the planning of any prospective "unified federal program." NASA will continue to work closely with whatever new government mechanisms are developed to transfer technology.

"PINGER" USE FOR LOST OBJECTS AT SEA

Question 9. Dr. Paine, in your statement, you discuss a small pinger for locating lost objects in the sea. Has the Department of Defense shown any interest in this or have you suggested that they might consider the use of this to put on major and expensive pieces of equipment that may be lost? I am thinking of a few years ago when an aircraft crashed and we lost a couple of nuclear weapons which took a long time to locate and we finally found them in waters off the coast of Spain?

Answer. We have suggested possible application of the "pinger" to several elements of the Department of Defense, and we understand that they are using it in aircraft, torpedoes, nose cones, as navigation markers, and on underwater equipment and systems. We have also publicly announced the "pinger" through the issuance of NASA Tech Brief No. 66–10315 in May 1966.

Senator CANNON. Thank you very much, and as I said, I will make a statement on the floor advising the Senators that this room will be opened and that the exhibits here will be on display for 2 days.

Thank you very much, Doctor.

(Whereupon, at 12:15 p.m. the committee adjourned.)

(The seven attachments to Dr. Paine's testimony are as follows:)

APPENDIX 1, ATTACHMENT 1

(Appendix 1 consists of 12 attachments)

NASA TECHNOLOGY UTILIZATION PROGRAM

TECHNOLOGY UTILIZATION

The purpose of NASA's Technology Utilization Program is to inform industrial, medical and educational communities of useful technological innovations resulting from NASA's research and development programs. These are the by-products of NASA's work. Nevertheless, many of these by-products have important technological (and economic) applications in a wide variety of often unrelated activities.

The Technology Utilization Program is described in the booklet entitled: "Useful New Technology from Aerospace Research and Development" (Attachment 1).

This Appendix includes a sample Tech Brief (Attachment 2) ; abstracts of representative Tech Briefs (Attachment 3) ; a listing of the more than 3000 Tech Briefs published to date (Attachment 4) ; a listing of Technology Utilization Conferences (Attachment 5) ; a bibliography of reports relating to the Technology Utilization Program (Attachment 6) ; a listing of Special Publications on Technology Transfers (Attachment 7) ; a list of available computer programs (Attachment 8) ; a number of examples of technology transfers (Attachment 9) ; a list of Patent Licenses granted by NASA (Attachment 10) ; the booklet "U.S. Patents for NASA Inventions Available for Licensing in the United States" (Attachment 11) ; and the booklet "Significant NASA Inventions Available for Licensing in Foreign Coutries" (Attachment 12).

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USEFUL NEW TECHNOLOGY
From Aerospace Research and Development

New Technology Information Services
Available to Industry
and Other Interested Groups

TECHNOLOGY UTILIZATION PROGRAM

National Aeronautics and Space Administration

DOWN TO EARTH FINDINGS FROM SPACE RESEARCH

The challenge of building machines that can function and keep men alive in space is daily expanding the skills and knowledge of America's engineers, scientists and educators.

At the same time, the many by-products of aerospace research by the National Aeronautics and Space Administration and its contractors are finding increasing use in a wide variety of non-aerospace activities.

To provide timely and useful information about the results of new space technology to the Nation's industrial-professional-educational complex is the goal of NASA's Technology Utilization Program. This program is a planned, continuing effort to locate aerospace-related inventions, new scientific knowledge and technical skills and to make them available to potential users in the civilian economy.

This booklet describes the various activities of the NASA Technology Utilization Program which are designed to inform the industrial, educational and medical communities of useful technological innovations resulting from NASA's aerospace research and development programs.

Information reported in the Technology Utilization Program includes new or improved techniques, procedures, programs, products, devices, materials, processes, compositions, systems, machines, articles, fixtures, tools, methods and scientific data. In essence, anything developed by NASA or under NASA contract represents a potential return on the taxpayers' investment in the space program.

Products resulting from the Technology Utilization Program range from the mundane to the exotic. An example of the former is a silicone sealant, a super glue, developed for use on spacecraft, which is now available on the shelves of hardware stores across the country. A more dramatic transfer of space technology is an electronic switch that can be activated by eye movements of an astronaut when high gravity forces might limit his arm and leg movements. The switch can be adapted for non-space uses, including self-guidance by partially paralyzed patients in wheel chairs.

Many of the benefits of the Technology Utilization Program are intangible, such as the increased interest on the part of companies working on NASA contracts to apply new managerial systems, techniques and procedures to pressing social problems in such fields as health care, education, crime prevention, pollution control and waste disposal.

To date, scores of new technical developments designed to meet the needs of the space program have been transferred or adapted for use outside that program. Many transfers are complete and direct; others may be indirect and in the form of bits and pieces of information assembled to provide usable packages of transferable data.

NASA'S MISSION CREATES NEW TECHNOLOGY

THE COMPUTER TECHNIQUE developed to clarify photographs transmitted from the Moon and Mars to Earth can also enhance the value of X-ray pictures for medical diagnoses.

Rainy-day auto accidents are being reduced as much as 90 percent in some places by grooving pavement, as a result of NASA studies of aircraft skidding on wet runways.

A sensor for wind tunnel research, smaller than the head of a pin, can be inserted by means of a hypodermic needle into a vein or artery to measure blood pressure without interfering with a patient's circulation. A West Coast hospital has used the sensor to evaluate implantation of artificial heart valves.

These are some of hundreds of uses of space technology in industry, medicine, education, and other activities here on Earth. The results of aerospace research and development—inventions, data, concepts, designs, discoveries, materials, processes, devices, techniques, computer software, and managerial methods—are made widely available by the NASA Technology Utilization Program that this booklet describes.

The scope, breadth, and complexity of NASA's mission to explore and develop peaceful uses of outer space demand a great variety of new knowledge. Space research is yielding both incremental advances in fabrication processes and quantum jumps in the state of some arts. This is obvious when you consider such unprecedented requirements as these:

A *communication network* of 21 stations (extending from Point Barrow, Alaska, to Carnarvon, Australia), controlled through two computer centers, to direct faraway vehicles. . . *Heat shields* to withstand 20,000°F, *batteries* that do not weaken at −100°, and *gloves* with which a man can hold an object at any temperature from −170 to 250° for 5 minutes. . . . *Packaging*

SPECIALIZED TRANSDUCER . . . . . a transfer example

A transducer developed for the Manned Spacecraft Center to measure the impact of the Apollo spacecraft Command Module during water landings is being used in the fitting of artificial limbs. The transducer is smaller than a dime and weighs less than an ounce. The sensing diaphragm is stainless steel and the whole unit is waterproof. As used in the Command Module, or in the hospital, it will respond to static or dynamic changes in pressure, and is not affected by temperatures between freezing and 120°F.

of 36 rocket engines, a power plant, air-conditioning and environmental control equipment, escape and survival aids, instrumentation, and guidance, control, communication, and recording apparatus, along with three men, in a relatively small vehicle. . . . A *braking system* to slow a vehicle from 24,000 mph to the landing speed of a helicopter without atmospheric help.

To meet such needs, thousands of scientists and engineers are producing new technology faster than it can be disseminated by traditional means. How can this great national resource be tapped by a machine operator in Wisconsin, an educator in Oklahoma, a medical researcher in Boston, and a design engineer in Cleveland? This is the challenge that the NASA Technology Utilization Program was created to meet. It has four basic purposes:

- To increase the return on the national investment in aerospace research by encouraging additional use of the results.
- To shorten the time gap between the discovery of new knowledge and its effective use in the marketplace.
- To aid the movement of new knowledge across industrial, disciplinary, and regional boundaries, and importantly
- To contribute to the development of better means of transferring knowledge from its points of origin to other points of potential use.

Breathing Sensor . . . . . . a transfer example

Infants, comatose children, or adult patients sometimes require surgical implantation of a tracheotomy tube in the windpipe to ease breathing. If the tube is clogged, cutting off breathing, brain damage or death can result within from two to four minutes.

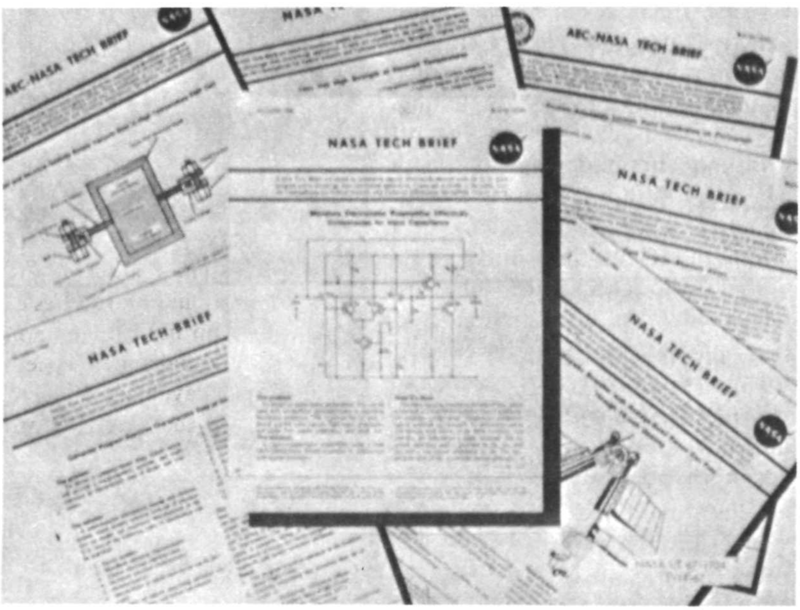
Ordinarily a full-time nurse is required, who checks the tube visually and takes immediate corrective action when necessary. Integrated circuitry, designed and fabricated for aerospace use by NASA's Ames Research Center, has been modified to note differences in temperature of air passing through the tube, and actuate an audible or visible alarm within 10 seconds of any change. The signal can be given at a nurse's station, or in another room if the patient is at home. Thus the patient's care is improved and facilitated.

HOW NEW TECHNOLOGY IS RECORDED

NASA COLLECTS THE RESULTS of aerospace-related research and development from all parts of the world to support its work. This collection now totals nearly 600,000 indexed documents, most of which have been abstracted and microfilmed. This aerospace data and information collection is a useful national resource which is made available to the industrial, educational, medical and professional complex through the NASA Technology Utilization Program.

Each of NASA's field installations has a Technology Utilization Officer. His assignment is to identify, document and evaluate new technology generated by NASA and its contractors and to assure its rapid availability to potential users outside as well as within the aerospace community. These officers administer a special clause in NASA's contracts with private companies that requires them to report to NASA new technology developed in the course of their work. New technology that is thus reported and deemed to have commercial potentialities is announced to business and industry in appropriate ways:

A *Tech Brief* is the most commonly used announcement medium.



Tech Briefs: Concise descriptions of inventions, discoveries, and other technological advances from NASA programs.

It is a one- or two-page bulletin concisely describing an innovation and explaining its basic concepts and principles. The reader may obtain more information about it, including test data, drawings, and specifications, by writing to the Technology Utilization Officer whose address is given on the Tech Brief. Many of the innovations announced in this way must be modified to be useful to the readers of these briefs, but the concepts stimulate thought, and analogs of the hardware described often can be developed for many uses.

Six categories of Tech Briefs are issued: Electrical (electronic), Physical Sciences (energy sources), Materials (chemistry), Life Sciences, Mechanical, and Computer Programs. Cumulative indexes to Tech Briefs are issued to lead engineers to NASA's solutions to problems similar to those that may arise in their own work.

TU Compilations provide a collection of many related ideas into a single book, covering the general subject. These are collections of brief statements of innovations, all in a related field, generously illustrated and, taken together, a workbook on a particular field at the practical level. Recent examples include "Machine Shop Measurement" and "Tools, Fixtures, and Test Equipment for Flat Conductor Cables".

Technology Utilization Reports describe innovations of special significance or complexity. These are more detailed announcements than Tech Briefs, and bear such titles as "Joining Ceramics and Graphite to Other Materials", "Induction Heating Advances: Applications to 5800°F" and "Constructing Inexpensive Automatic Picture-Transmission Ground Stations".

Technology Surveys consolidate the results of NASA-sponsored research-and-development efforts which have advanced whole areas of technology. Noted authorities on the subject matter write these "guidebooks" for NASA to help others benefit from the accomplishments described. Magnetic tape recording, solid lubricants, thermal insulation systems, high-velocity metalworking, and advanced valve technology are examples of the topics that have been surveyed.

Conference Proceedings are also published to disseminate technology. NASA sponsors several conferences each year for particular industries and groups. At such meetings scientists and engineers who have made major contributions to technology review their work for potential beneficiaries of it in an industrial community. Conferences held on "Pavement Grooving and Traction Studies" and "Selected Technology for the Electric Power Industry" are typical examples.

SPECIALIZED INFORMATION SERVICES

REGIONAL DISSEMINATION CENTERS

New knowledge is acquired in bits and pieces more often than in readily usable packages. To solve a problem in one context, information acquired for a dozen other purposes often must be pulled together, applied to the specific situation, and possibly expanded by further study of individual requirements.

Six Regional Dissemination Centers established by NASA help potential users of new technology obtain it in packages appropriate to their needs. No two of these centers are alike. Each one, however, is based at a university or not-for-profit research institute, and staffed with professional personnel skilled in the use of computer search-and-retrieval techniques to assemble information. These centers establish Government-university-industry partnerships by serving fee-paying industrial clients, both large and small, in a variety of ways:

Current Awareness Searches: Computer tapes bearing 6000-or-so new citations of scientific and technical reports are searched each month for items of likely value to each client. This is done by machine matching an "interest profile" of the client's objectives, problems, needs, and desires against indexed descriptions of aerospace researchers' findings. Specialists then screen the citations obtained in this way for relevance and quickly forward the results to the client. He then may request and receive full copies of whichever documents among those cited that he decides may be useful to him.

Retrospective Searches: More thorough searches are made in response to clients' specific questions. Computer tapes bearing citations of previous as well as the most recent additions to the aerospace library are machine searched. The output is evaluated by the RDC's experts and sent to the company or person who posed the question. Full copies of the documents located in this way are also sent when requested.

Standard Interest Profiles: The regional centers prepare and use profiles of this type when they have numerous clients with closely related interests. Like readymade clothing, these profiles reduce the cost to customers who do not require custom-tailored information service.

Listings of Technology Utilization Publications

Abstracts and listings of all Technology Utilization Publications are provided in the booklet entitled "Transferable Technology—Fall 1969". This booklet can be obtained from the Technology Utilization Division, NASA Headquarters, Washington, D.C. 20546, or from any NASA installation Technology Utilization Office listed on the inside back cover.

Special Publications. RDC's send the Technology Utilization Publications described on page 5 to their clients each week, and supply additional detailed information and backup data to particular clients on matters of special interest to them.

Assistance to Management. In addition to sifting and providing basic information, the regional centers increase its value to their clients. They help companies systematize their collection and use of knowledge generated elsewhere. They call attention to developments and trends that may affect both their clients' current operations and their long-range plans. Their services are helpful in

Product innovation
Process improvement
Cost reduction
Resource allocation
Setting R&D priorities and avoiding duplication
Continuing education of professional personnel
Improving management

and in many other ways. Each RDC is responsive to a specific geographic and economic environment. Hence their services and their fees vary. Their addresses are given below, and a prospective client may consult any of them about its offerings and charges.

All NASA Technology Utilization publications may be obtained through these dissemination centers:

AEROSPACE RESEARCH APPLICATIONS CENTER, *Indiana University Foundation*, Bloomington, Ind. 47405. Phone 812 337-7970.

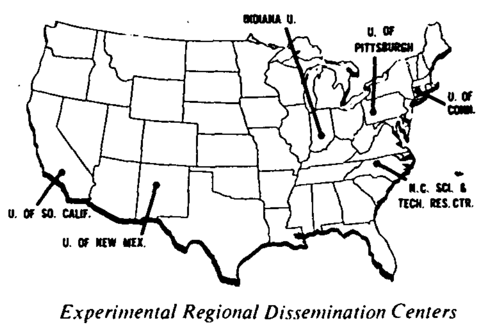
KNOWLEDGE AVAILABILITY SYSTEMS CENTER, *University of Pittsburgh*, Pittsburgh, Pa. 15213. Phone 412 621-3500, ext. 6352.

TECHNOLOGY APPLICATION CENTER, *University of New Mexico*, Box 185, Albuquerque, N. Mex. 87106. Phone 505 277-3118.

NEW ENGLAND RESEARCH APPLICATION CENTER, *University of Connecticut*, Storrs, Conn. 06268. Phone 203 429-6616.

NORTH CAROLINA SCIENCE AND TECHNOLOGY RESEARCH CENTER, Post Office Box 12235, Research Triangle Park, N.C. 27709. Phone 919 834-7357 or 549-8291.

WESTERN RESEARCH APPLICATIONS, CENTER, *University of Southern California*, Los Angeles, Calif. 90007. Phone 213 746-6133.



Experimental Regional Dissemination Centers

EKG Transmitting System . . . . . . a transfer example

A physician can now obtain electrocardiogram (EKG) data on a patient before he ever sees him. An EKG, taken in the ambulance transferring the patient to the hospital, is transmitted by radiotelemetry direct to the physician who will handle the case. Technology developed at NASA's Flight Research Center, plus interest by physicians and a local ambulance firm in improved patient care, made the development possible. A system of dry, spray-on electrodes is used. The spray-on electrode was announced in a NASA Tech Brief, and is currently being marketed by a small firm. Another company is planning to make the electronic equipment commercially available.

COMPUTER SOFTWARE AND MANAGEMENT INFORMATION CENTER (COSMIC)

COSMIC has been established by NASA to enable users of computers to benefit from the millions of dollars that NASA has invested in the development of computer programs. This Center, at the University of Georgia, collects, evaluates and distributes tapes, card decks, program listings, and machine-run instructions. COSMIC and all Regional Dissemination Centers, described previously, sell "software" to potential users at prices determined by the cost of reproduction and distribution. Further information about this service may be obtained from any of the Regional Dissemination Centers listed on the previous page, or

Director
COSMIC
University of Georgia
Computer Center
Athens, Georgia 30601

COSMIC serves as the central clearinghouse and dissemination outlet for computer programs and related information developed by NASA and its contractors. The Center receives, evaluates and checks out the software, adding to its inventory those items which are operational and of potential value in a wide range of applications. The project has established a firm

base of support in the industrial, educational, and business communities, with nearly 20,000 items being disseminated to date. Computer programs are passed on to users at very considerable savings to the user, the development cost having been originally borne by NASA. It is estimated that the average purchaser of a program from COSMIC saves approximately 50-90% of the cost of developing a similar program.

New items are continually being added to the computer program inventory: by January 1970 nearly 1000 complete programs and documentation packages will be available.

Recently an important milestone was passed when the Department of Defense joined NASA in this effort and agreed that computer software developed for DOD use will also be made available to industry through COSMIC.

This project is proving to be an important innovation in the transfer of computer applications and offers very substantial savings to the economy.

A new announcement journal, entitled Computer Program Abstracts, *has been issued by the NASA Office of Technology Utilization. This quarterly periodical is available on an annual subscription basis from the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402.*

Cardiac Catheter ..... a transfer example

A sensor developed at Ames Research Center is smaller than the head of a pin and can be inserted into a vein or artery to measure blood pressure without interfering with circulation. Less than 0.05 in. in diameter, the probe can be inserted through a standard hypodermic needle. The original version of this sensor was a transducer developed to provide pressure distribution measurements over the surfaces of small wind tunnel models. The National Heart Institute has monitored the progress toward commercial development of these cardiac catherers.

OTHER TECHNOLOGY UTILIZATION ACTIVITIES

BIOMEDICAL APPLICATION TEAMS

Since instruments, mechanisms, and systems created to explore space are also often very helpful to biologists, surgeons, and physicians, NASA has taken additional steps to disseminate information to them. Three Biomedical Application Teams are now facilitating communication and cooperation between aerospace and biomedical researchers. Each team includes representatives of both professional communities. These teams prepare "Medical Problem Abstracts" that are used both to search NASA's computerized information bank for relevant discoveries and innovations and to solicit guidance and suggestions from aerospace scientists and technicians for biomedical specialists. Technology Utilization Officers help these teams tap the resources of NASA field installations. Further information about these teams' activities may be obtained from the Director, Biomedical Application Team, at any one of the three research institutes listed below:

MIDWEST RESEARCH INSTITUTE
425 Volker Boulevard
Kansas City, Mo. 64110

SOUTHWEST RESEARCH INSTITUTE
8500 Culebra Road
San Antonio, Tex. 78206

RESEARCH TRIANGLE INSTITUTE
Post Office Box 12194
Durham, N.C. 27709

HEART MONITOR ...... a transfer example

An investigator working under a NASA grant at the Duke University Medical Center wanted to monitor heart action more precisely by measuring electrical signals simultaneously along 15 points on a small area of the heart wall. For this, he needed a probe that would insure good contact at all 15 points and which would not result in heart wall damage upon insertion. The NASA-sponsored Biomedical Applications Team at the Research Triangle Institute explained the problem to an instrument engineer. He designed a 15-electrode probe within an ordinary hypodermic needle. It was fabricated, tested, found satisfactory, and is now in use.

INTERAGENCY ACTIVITIES.

The technology generated by one Federal agency is often found useful to another agency concerned with an utterly different facet of the Nation's welfare. Hence NASA has entered into numerous agreements to help other Government agencies benefit from its research-and-development efforts, and thus to multiply the dividends to the public from expenditures for spacework. These joint programs are expanding the channels for technology transfer into such activities as law enforcement, assistance to small businesses, rehabilitation of handicapped persons, regional economic development, transportation, and air and water pollution.

Cooperative efforts between NASA and the Small Business Administration continue to broaden. Such activity includes seminars, workshops, publications and other experimental dissemination efforts.

Continuing experimental programs are underway with several other federal agencies. These efforts are directed toward the application of NASA generated technology to technical problems identified within these mission-oriented agencies. The user agencies with which NASA is working include among others: the Law Enforcement Assistance Administration (Department of Justice); the Bureau of Reclamation and the Federal Water Pollution Control Administration (both are in the Department of Interior); the National Air Pollution Control Administration (Department of Health, Education and Welfare); the Department of Transportation; and the Social and Rehabilitation Service (Department of Health, Education and Welfare). The interest areas which are of concern to these Agencies and in which NASA can make potential technological contributions include: management and technical information systems; weather modification; air and water pollution; highway safety; and many specific fields of medicine and biomedical technology.

EDUCATION ENRICHMENT MATERIALS

Another Technology Utilization activity is testing the feasibility of accelerating into graduate and advanced undergraduate engineering curricula new scientific and technical knowledge resulting from aerospace research and development. Oklahoma State University, under contract to NASA, selects source material from NASA R&D reports from which instructional monographs are prepared. These texts are written in an educational format for use on a trial basis as supplementary teaching aids in classroom situations.

Two hundred and sixty-two (262) professors at 111 universities have requested monographs for review and classroom use. Evaluation reports received are positive, and it is hoped that another institution will sponsor further development of the concept as a means for improving the quality of formal engineering education.

Reports received from practicing engineers in industry reveal that the same educational monographs have utility and value as a teaching aid in continuing education programs carried out by the companies they represent.

PATENTS AND LICENSES

NASA's PATENTS AND LICENSE REGULATIONS are a further aid to the transfer of technology. They encourage full industrial use of inventions that result from research-and-development work performed by employees of NASA and its contractors. They both stimulate the making of inventions and provide incentives for their integration into the economy.

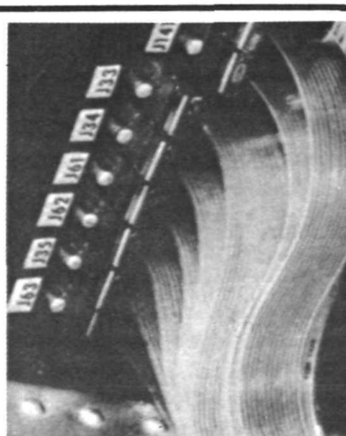
Under the Space Act of 1958, all new technology, including inventions, deriving from work under a NASA contract must be disclosed promptly to NASA. These inventions become the agency's exclusive property. NASA may waive all or any part of the rights in the invention to the contractor, however, if it is in the public interest to do so.

When a NASA contractor makes an invention and subsequently receives a waiver from NASA, the company obtains title to the invention, subject only to the reservation that the Government may have a nonexclusive license to use the invention. The recipient of the waiver is required to reduce the invention to a commercial form within a reasonable period of time and to file a patent application, or the waiver will be revoked.

To encourage the earliest possible commercial use, all inventions owned by NASA for which a patent application has been filed, or that have been patented on behalf of NASA, are available for royalty-free license by American firms. If the invention is not reduced to commercial form within 2 years after a patent has been issued, NASA will make the invention available on an exclusive basis in order to stimulate interest in using it commercially. A few inventions are also available for licensing by foreign firms.

Inquiries concerning NASA patent policy and the licensing of NASA-owned inventions may be directed to the NASA patent counsel at any NASA field installation or to the Assistant General Counsel for Patent Matters, NASA, Washington, D.C. 20546.

The development of flat conductor cable technology at Marshall Space Flight Center has reached a highly successful stage. These cable forms have been found to offer advantages to electrical-system designers by saving weight, space, cost and lead time, and by possessing excellent reliability and uniform electrical characteristics. Concurrent with development of these cables and their connectors, a large family of tools, fixtures, and test equipment has evolved to advance their preparation, installation, and repair.



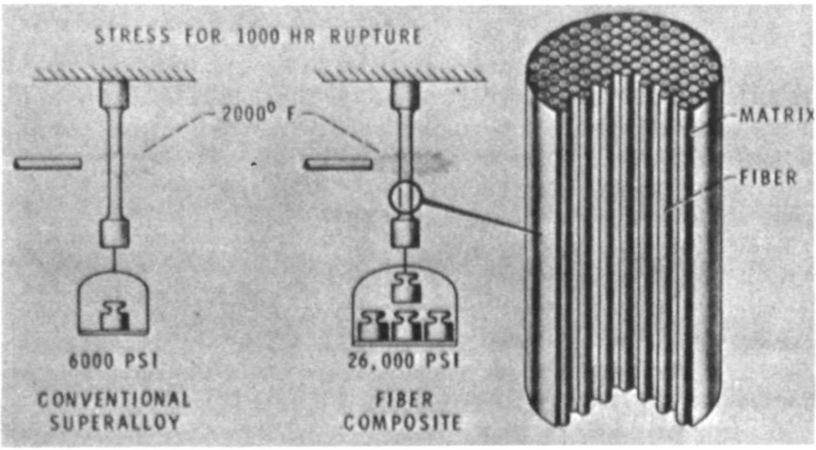
Flat Conductor Cable Technology

SOME TYPICAL TECHNOLOGY TRANSFERS

Computer Program Utilization

Maximal use of computer programs with general purpose potential is encouraged by making them available at a fraction of development cost. In one example, a software package developed to optimize a group of design parameters, has been used by over 30 different enterprises for a variety of applications. These range from "increasing the effectiveness of public health surveys" to "optimizing hydroelectric power generation".

Tungsten Fiber Alloy



A tungsten fiber-reinforced nickel superalloy that is four times as strong as conventional nickel-base superalloys is described in Tech Brief 68-10369. This new composite material successfully utilizes the strength of refractory metal fibers to reinforce metals at high temperatures. It is useful where higher strength or a greater strength-to-density ratio is required in high-temperature systems and components. Examples of potential applications include high-temperature turbine components and turbine-generator components for advanced electrical power systems.

Reliability Technique

An analytical technique has been devised that permits a comparison of the reliability of alternate mechanical designs. This technique has been employed by a small manufacturer of mining equipment, conveyor systems and cargo handling gear, such as winches, lifts, cranes, and the like. Under contract to a Pascagoula, Mississippi shipbuilder, the company was able to provide valid data on systems reliability and maintainability.

Heat Sensor

Under contract to Manned Spacecraft Center, a NASA contractor has developed a consumable thermocouple which is capable of continuously monitoring the temperature of a spacecraft heat shield over the range of $-250°$ to $+5000°F$. Sensors of this type may be used in metal-treating furnaces and in other high-temperature reactive environments. A West Coast firm is integrating these thermocouples into its product line.

Reflective Superinsulation

A NASA contractor has developed an insulation material to maintain room temperatures in the extreme conditions of space. This superinsulation consists of crinkled aluminized plastic and has high mechanical strength, more resiliency, and less space-weight requirements than any comparable material. The developer has incorporated it into a line of blankets for sportsmen, a radar-reflective air-sea rescue signal, and an emergency rescue blanket. All of these items are commercially available.

Non-destructive Testing

A major industrial firm has evaluated the effect of NASA-disseminated information on non-destructive testing. This technique of evaluating the strength and other characteristics of materials has contributed about $1 million per year in savings by allowing the use of materials at a higher proportion of their true strength. That means lighter, more reliable structures.

New Machining Device

A firm under contract to Marshall Space Flight Center has developed a lightweight, portable router that can machine heavy subassemblies in place, has a variable-speed drive, and is uniquely capable of making cuts while following more than one contour. A shipbuilding company intends to use design features of this device to develop a router to cut in-service stainless steel nuclear reactor pipe. Unlike the prior method of manual cutting which results in debris inside the pipe, the new router will employ a vacuum source to remove all cuttings.

Training of the Physically Handicapped

A sling support device was developed by Langley Research Center for the purpose of acquainting astronauts with gravity conditions on the lunar surface where the force of gravity is one-sixth that found on Earth. A NASA-sponsored Biomedical Application Team at Southwest Research Institute was aware of the need for a device with which to train and rehabilitate physically handicapped persons. The sling support device was thus made known to investigators at the Texas Institute for Rehabilitation and Research, who, with assistance from Langley personnel, have adapted the lunar gravity simulator to suit TIRR's needs in training the handicapped. The TIRR device is in use at their clinic in Houston, Texas.

Digital Image Processing

Pictures of the surface of Mars transmitted to Earth from the Mariner IV Spacecraft, and those of the lunar surface taken by cameras on Surveyor I, were not reproductions of actual images constructed from radio signals received from space. Published photographs were enhanced by a special digital filtering process developed at the Jet Propulsion Laboratory. Application and further refinement of this photo enhancement technique shows great promise for revealing details heretofore unobtainable in medical x-rays.

New Class of Plastics

Technologists, working under contract to the NASA Lewis Research Center, have developed HYSTYL resins, a new class of thermosetting polyurethane plastics with improved strength, and with thermal and chemical stability. These new plastics, described in NASA Tech Brief 67-10197, have aroused interest from a maker of grinding wheels, an electronics manufacturer, a casket-manufacturing company, a firm supplying aircraft and missile components, a chemical manufacturer, and others. A small company capitalized at over $1,000,000 has been formed to produce and market these plastics.

New Company Established

Results of research on energy storage capacitor technology described in Tech Brief 66-10291 were instrumental in the establishment of a new company in San Diego, California. The firm is constructing a 60,000 square foot plant to house development laboratories and manufacturing facilities for production of high voltage electronic components and systems, including million-volt pulse generators and high voltage pulse-discharge generators.

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SUMMARY OF TU INFORMATION SERVICES

TECH BRIEFS are sold on subscription by the *Clearinghouse for Federal Scientific and Technical Information*, Springfield, Virginia 22151. A 1-year subscription for all six categories of Tech Briefs is $20. A set of all Tech Briefs issued prior to January 1969 is $90. A Cumulative Index to Tech Briefs is $3.

REPORTS, SURVEYS, HANDBOOKS, CONFERENCE PROCEEDINGS, and other Special Publications are also sold by the *Clearinghouse for Federal Scientific and Technical Information* (see address above) at prices ranging from $3 to $10. Many of these publications are also sold by the Superintendent of Documents, *U.S. Government Printing Office*, Washington, D.C. 20402.

ABSTRACT JOURNALS are published semimonthly. *Scientific and Technical Aerospace Reports* (STAR) announces new report literature; *International Aerospace Abstracts* (IAA) covers published literature. The *U.S. Government Printing Office* (see address above) sells single copies of STAR for $2.25 and annual subscriptions for $54. The American Institute of Aeronautics and Astronautics, Inc., 750 Third Avenue, New York, N.Y. 10017, accepts annual subscriptions to IAA for $54.

REGIONAL DISSEMINATION CENTERS throughout the country are listed on page 7. Their annual fees range upward from $50 to more than $5000, depending on the volume, type, and extent of the services to a client.

COMPUTER PROGRAMS are sold by COSMIC, University of Georgia Computer Center, Athens, Ga. 30601. Prices are based on the cost of reproduction and handling of the programs. For a catalog and more information, write to the Director, COSMIC.

BIOMEDICAL APPLICATION TEAMS at the institutes listed on page 10 assist qualified researchers. Individual arrangements must be made for this service. Inquiries may be forwarded to the Director, Biomedical Application Team, at any of these institutes.

PATENT LICENSING arrangements may be made with the Assistant General Counsel for Patent Matters, Code GP, NASA Headquarters, Washington, D.C. 20546.

INTERAGENCY COOPERATION or any aspect of the NASA Technology Utilization Program may be discussed by consulting the Director, Technology Utilization Division, NASA Headquarters (address above), or a Technology Utilization Officer at a field installation listed on the inside back cover.

NOTE

Pages 91-234 have been omitted from this issue.

These pages contain Attachments 2 through 8 of Appendix 1, which are listed on page 73.

Information concerning any of this material may be obtained by writing:

Office of Technology Utilization, National Aeronautics and Space Administration, Washington, D.C. 20546.

RESEARCH FACILITIES

INSTITUTION	TITLE
Rensselaer Polytechnic Institute	MATERIALS RESEARCH CENTER
Stanford University	EXOBIOLOGY LABORATORIES
University of Chicago	ASTROPHYSICS & SPACE RESEARCH LABORATORY
University of Iowa	PHYSICS & MATHEMATICS BUILDING
University of California at Berkeley	SPACE SCIENCES LABORATORY
Harvard University	BIOMEDICAL LABORATORIES
University of Minnesota	SPACE PHYSICS LABORATORIES
Massachusetts Institute of Technology	CENTER FOR SPACE RESEARCH
University of Colorado	LABORATORY FOR SPACE PHYSICS
University of California at Los Angeles	SLICHTER SPACE SCIENCES LABORATORY
University of Wisconsin	THEORETICAL CHEMISTRY INSTITUTE
University of Michigan	SPACE RESEARCH LABORATORY
University of Pittsburgh	SPACE RESEARCH & COORDINATION CENTER
Princeton University	PROPULSION RESEARCH LABORATORIES
Lowell Observatory	PLANETARY RESEARCH CENTER
Texas A&M University	TEAGUE SPACE RESEARCH CENTER
University of Maryland	SPACE SCIENCES CENTER
University of Southern California	HUMAN CENTRIFUGE
Cornell University	RADIOPHYSICS & SPACE RESEARCH CENTER
Rice University	SPACE SCIENCE & TECHNOLOGY LABORATORY
Purdue University	ROCKET TEST FIRING FACILITIES
Washington University at St. Louis	COMPTON RESEARCH LABORATORY OF PHYSICS
New York University	AEROSPACE SCIENCES BUILDING
Georgia Institute of Technology	SCIENCE & TECHNOLOGY CENTER
University of Arizona	SPACE SCIENCES BUILDING
University of Illinois	AEROSPACE RESEARCH CENTER
Polytechnic Institute of Brooklyn	BASSETT AEROSPACE RESEARCH LABORATORY
Case Western Reserve University	SPACE ENGINEERING BUILDING
University of Rochester	SPACE SCIENCES CENTER
University of Florida	SPACE SCIENCES RESEARCH LABORATORY
University of Minnesota	SPACE SCIENCE LABORATORY
University of Denver	SPACE SCIENCES LABORATORIES
Stanford University	SPACE ENGINEERING BUILDING
University of Wisconsin	SPACE SCIENCE & ENGINEERING CENTER
University of Washington	AEROSPACE RESEARCH LABORATORY
University of Kansas	SPACE RESEARCH & TECHNOLOGY LABORATORY
National Academy of Sciences	LUNAR SCIENCE INSTITUTE

APPENDIX 4

UNIVERSITY RESEARCH FACILITIES

BUILT UNDER NASA GRANT

UNIVERSITY RESEARCH FACILITIES

In the decade of the 1960's Research Laboratories were built under NASA grants at 34 institutions. Facilities include Space Sciences Laboratories, Materials Research Centers, Biomedical Laboratories and Propulsion Research Laboratories. In total, these laboratories have a floor area of nearly 1.5 million square feet.

Important research has already been carried out in these facilities. Equally important, these facilities have provided the research opportunities for advanced work toward doctoral degrees in the many disciplines. A substantial portion of the more than 2,100 young men and women who received their doctoral degrees under the NASA predoctoral training program did their graduate research in these facilities.

SPACEMOBILE PROGRAM

The Space Science Education Project, also called "Spacemobile," provides lectures and consultants for school assemblies, classrooms, curriculum committees, and teacher workshops in aerospace education.

In calendar year 1969:

Total live audience	3, 306, 410
Total live lecture/demonstrations	14, 870
Estimated TV audience	20, 391, 500

Evaluation

The Council of State Science Supervisors reports that this program affected the career choices of 20 percent of college students polled; and that 45 percent of high school and 42 percent of college students polled reported an increased use of libraries and their needs for space-related reference materials.

Scheduled by the States.—The Spacemobile units are in great demand, being booked into schools a year in advance. The programs have been reported by school administrators as being highly motivational and stimulating to students.

PUBLICATIONS

NASA produces and distributes informational/educational publications for the general public and for responses to teacher-student requests. They provide orientation, background and knowledge about NASA projects such as *Apollo*, *Report from Mars*, *Putting Satellites to Work*, *Space Physics and Astronomy*, and several others.

NASA Facts, 4- to 8-page pamphlets or wall charts for classroom use and libraries. A special "Science Series" is directed at the secondary school teachers and students. Others are being prepared for use in the lower grades. Examples are: *The Countdown*, *Weightlessness*, *Solar Cells*, *Orbits*, *and Revolutions of Spacecraft.*

Evaluation

Many letters from teachers and students indicate that these publications serve to stimulate interest and motivate teachers to keep abreast of developments in space science and technology.

AUDIO-VISUAL MATERIALS

NASA develops and distributes 16mm sound films on NASA research programs, such as *Living in Space*, *Electric Propulsion*, *A New Look at an Old Planet*, *Men Encounter Mars*, *Seeds of Discovery*, and others.

Film strips and slides on a variety of subjects such as *Geology from Space*, *Space Food*, *Men to the Moon*, etc.

Eight millimeter film "loops" on single concepts for science classroom use.

Audio and video tapes and short film clips for educational television and classroom use.

Evaluation

These audio-visual materials are in continuous demand by schools, colleges, and educational TV. Report cards indicate they are of great interest and educational value.

Evaluation

In evaluating NASA's teacher educational services, the Council of State Science Supervisors recently reported that (1) 85 percent of the teachers who attended aerospace workshops stated that they introduced aerospace into their teaching in subsequent semesters; (2) that 76 percent of the students stated they understood better science principles taught in class because they had been introduced by teachers through an aerospace frame of reference.

NASA provides no funding for either students attending or institutions sponsoring teacher educational projects in aerospace.

YOUTH SERVICES

1. Youth Science Congresses

Organize and conduct, through the National Science Teachers Association, the Youth Science Congress Program. In 1969, twelve Congresses were conducted at nine NASA Centers plus St. Louis, Minneapolis, and Denver. To each are invited 20 youngsters who are selected on the basis of their science research papers.

At each Congress the students present their papers to an audience of peers and *scientists* from NASA, universities and industry. Give and take discussion follows.

The program is in its seventh year. A total of 1,000 students have participated.

2. Science Fairs

NASA also participates in the annual International Science Fairs sponsored by Science Services, Inc. We provide honorary awards such as certificates, NASA publications, and field trips to NASA Centers.

3. Other

NASA provides publications, films, speakers and tours to such organizations as Boy Scouts, National Association of Rocketry, Junior Engineering Technical Society, etc.

Evaluation

A preliminary report of a survey of participants in the Science Congresses and Science Fairs indicates that about 90 percent of them were influenced in their choices of careers in scientific and technical fields.

CAREER GUIDANCE

NASA has developed special publications on aerospace jobs and careers at the elementary, junior high, and high school levels. These are used in responding to an average of about *600 such inquiries a month from students and teachers.*

Aerospace Curriculum Resource Guide.—Project cost $23,000. Published 13,000 copies. For teachers of all subjects, Grades K–12. Developed for Massachusetts Schools by Massachusetts State Department of Education. Used nationally. Distributed by Headquarters ROTC to its high school units as guide for developing cross-disciplinary aerospace teaching. Distributed by the Foreign Policies Association to leaders in elementary school social studies teaching.

Space Resources for the High School: Industrial Arts Resource Units.—For secondary school industrial teachers. Project cost $18,700. Published 40,500 copies. Widely used nationally. Stimulated curriculum enriching project of the American Industrial Arts Association. Used in course-of-study updating by States of Georgia and Florida, and Commonwealth of Puerto Rico.

Space Resources for Teachers: Biology.—Project cost $24,950. For secondary school biology teachers. Published 5,000 copies. Professional interest in it is high with seven regional and national conventions of the National Science Teachers Association devoting concurrent sessions to discussing it.

Space Resources for Teachers: Space Science.—Project cost $11,615. Published 5,000 copies. For secondary school science teachers. Covers space implications for biology, physics, chemistry, and mathematics. Has had concurrent sessions of five regional and national conventions of the National Science Teachers Association devoted to it.

Evaluation

The *Bulletin* for January 1970 of the National Association of Secondary School Principals, under "Editor Comments," in calling attention to NASA secondary school curriculum bulletins, writes: "To help close the gap between what is happennig on the frontiers of science and technology and what is being taught in classrooms, the National Aeronautics and Space Administration has recently published four books that will be valuable additions to the professional libraries of secondary school teachers."

The January 1970 number of *Social Education*, the periodical of the National Council for the Social Studies, in an article "Space Age Curriculum" states ". . . the curriculum publications of the National Aeronautics and Space Administration (NASA) are far ahead of anything educational publishers have produced."

TEACHER EDUCATIONAL SERVICES

Includes assisting institutions of higher learning, professional associations, and regional, state and local school authorities to provide preservice and in-service teachers with sufficient understanding of America's aerospace activities to adapt what is appropriate to their teaching. The services include providing NASA's publications, curriculum supplements, films, speakers, spacemobile lecturers, and tours of installations, and also organizing and conducting courses, conferences, institutes and workshops.

The NASA Teacher Educational Services reach annually 25,000 teachers in 600–700 courses, institutes and workshops.—The reason for high teacher interest in aerospace is twofold: America's program in aerospace is (1) generating new knowledge; and (2) motivating student learning in science and all subjects.

expected dividends. Already, the dawning of the space age had impelled Americans to seek to improve their schools. That alone may be worth the cost of all our space rockets."

NASA employs a literal interpretation of the Space Act's directive to increase the scientific and technical capability of the Nation. We regard our undertakings as incomplete until their results have been made available to the country's elementary and secondary schools. Programs have been developed to facilitate the transfer of this new knowledge.

Working with universities, for example, NASA compiles the relevant information its programs produce into curriculum supplements (not textbooks) which are made available to teachers. This program helps fill the gaps between the appearance of new knowledge and the use of that knowledge in textbooks which are a long time in preparation and acceptance. The agency also works with current state school curricula.

The general approach of the agency's primary and secondary school programs is to offer teachers relevant information in useful formats. It is the teacher who makes the judgment on how and when to employ this new knowledge in the classroom. Central to this approach is an active program of NASA assistance to institutions of higher learning, state and local school authorities and professional associations in the conduct of courses, institutes and workshops for pre- and in-service teachers.

There is one major exception to the teacher-oriented NASA educational program: the Spacemobile offers lecture demonstrations directly to students. Nearly all Spacemobile schedules are established by state boards of education. The program reaches about 3 million students annually.

Descriptions and results of educational programs follow:

CURRICULUM RESOURCES PROGRAM

Provides teachers with publications which relate aerospace results to the several subjects, grades K–12. Useful also to curriculum and textbook writers who wish to update content with recent and relevant aerospace developments. Basic is its purpose of providing a stimulus and a model for similar non-NASA aerospace curriculum projects. The supplements are published both as books covering several topics and as leaflets dealing with a single topic; appropriate film loops are being prepared.

Examples are:

Teaching To Meet the Challenges of the Space Age.—For elementary teachers. Project cost $1,000. Published 120,000 copies. Being updated by Center for Urban Education, New York City, a USOE Title IV project.

Introducing Children to Space, the Lincoln Plan.—For elementary teachers. Project cost $8,950. Published 52,500 copies. Well regarded nationally. Served as starting point for USOE Title III aerospace curriculum projects in the schools of Eastern Nebraska.

The Planetarium, and Elementary School Teaching Resource.—Project cost $7,776. Published 60,000 copies. For elementary teachers and planetarium directors to relate aerospace to intermediate grade science.

Compatibility of Columbium Base Alloys with Lithium Fluoride. By R. W. Harrison and W. H. Hendrixson (NASA CR-1526).

TECHNICAL TRANSLATIONS

Titanium Alloys for Modern Technology. By N. P. Sazhin (NASA TT F-596).

Satellite Meteorology. By K. S. Shifrin and V. L. Gayevskiy (Eds.) (NASA TT F-589).

Perception of Space and Time in Outer Space. By A. A. Leonov and V. I. Lebedev (NASA TT F-545).

Radiophysics. 1965-1966: Radiophysical Investigations of Venus. By A. D. Kuzmin (NASA TT F-536).

SPECIAL PUBLICATIONS

Apollo 11: Preliminary Science Report (NASA SP-214).

Exploring Space With A Camera. Compiled and Edited by E. M. Cortright (NASA SP-168).

Weather Satellite Picture Receiving Stations.—Inexpensive Construction of Automatic Picture Transmission Ground Equipment. By C. H. Vermillion (NASA SP-5080).

Mariner-Mars 1969: A Preliminary Report (NASA SP-225).

Surveyor Program Results (NASA SP-184).

Earth Photographs from Gemini VI through XII (NASA SP-171).

In Fiscal Year 1969, more than 1.6 million copies of NASA publications were distributed. In addition, more than 3 million microfiche copies—microfilm carrying images for 60 pages each—were also sent out. The attached table gives a breakdown of our report distribution statistics.

NASA REPORT DISTRIBUTION STATISTICS FOR FISCAL YEAR 1969

Formal series (printed)	Titles	Copies	Recipient organizations
Special publications	69	241,500	2,573
Technical notes, technical reports, contractor reports, technical translations	945	1,417,500	2,573
Technical memorandums	202	30,300	150

Microfiche copies [1]	Titles	Microfiche cards	Copies	Average number of recipients
Not-printed NASA documents	10,216	17,360	3,211,500	230

[1] 4 by 6-sheet microfilm; each sheet carries images for 60 pages.

Appendix 3

IMPACT OF SPACE PROGRAM ON EDUCATION

The exploration of space has profound and continuing effects on U.S. education.

The shock of the first Sputnik prompted a dramatic re-evaluation of our scientific educational practices. Curricula changed. New maths and physics appeared. Instruction in other sciences was radically altered and updated, not only in expected evolutionary patterns, but also as a direct result of the flow of new knowledge. The results of this country's space programs and the needs of scientific and technological education now converge in a continuing dialogue that infuses new knowledge into the Nation's classrooms.

In the early days of space exploration Dr. Lee DuBridge said, "One hundred years from now the new kind of knowledge attained in space research will surely have paid untold, unforeseen, and un-

monographs, data compilations, handbooks, sourcebooks, and special bibliographies.

Technology Utilization Publications: This category of Special Publications includes information on technology used by NASA that may be of particular interest in commercial and other nonaerospace applications. Publications include Technology Utilization Reports, Notes, and Technology Surveys.

Listed below are representative titles of recent NASA publications in the various series.

REPRESENTATIVE TITLES OF NASA PUBLICATIONS

TECHNICAL NOTES

Fortran Program for Machine Computation of Group Tables of Finite Groups. By G. Allen, D. D. Evans, and P. Swigert (NASA TN D–5402).

Experimental Measurements of Expanding Storable-Propellant Products Simulated by Combustion of Gaseous Reactants. By R. Friedman, R. Gangler, and E. Lazberg (NASA TN–5404).

The Visual Acuity in Viewing Scaled Objects on Television Compared With That in Direct Viewing. By E. Long, Jr., and S. Long (NASA TN D–5534).

Some Factors Affecting the Stress-Corrosion Cracking of Ti-6A1-4V Alloy in Methanol. By W. B. Lisagor (NASA TN D–5557).

A Study of the Application of Heat or Force Fields to the Sonic-Boom Minimization Problem. By D. S. Miller and H. W. Carlson (NASA TN D–5582).

TECHNICAL MEMORANDUMS

A Review of Liquid Propellants. By R. O. Miller (NASA TM X–1789).

Synoptic Analysis of the Southern Hemisphere Stratosphere. By A. J. Miller and F. J. Finger (NASA TM X–1814).

A Procedure for Furnace Brazing Butt Joints in Tungsten-Uranium Dioxide Cermet Cylinders at 3000° C. By T. J. Moore and D. W. Adams (NASA TM X–1815).

Toxicity Problems in Plastic Hardware Designed for Biological Space-Flight Experiments. By R. Willoughby (NASA TM X–1818).

Design and Performance of a Heart Assist or Artificial Heart Control System Using Industrial Pneumatic Components. By J. A. Webb, Jr., and Vernon D. Gebben (NASA TM X–1953).

TECHNICAL REPORTS

The Effects of Molecular Structure on the Thermochemical Properties of Phenolic and Related Polymers. By J. A. Parker and E. L. Winkler (NASA TR R–276).

Self-Synchronizing Bi-Orthogonal Coded PCM Telemetry System. By W. Miller, R. Muller, T. Taylor, and J. Yagelowich (NASA TR R–292).

Principles of Optical Data Processing for Engineers. By A. R. Shulman (NASA TR R–327).

Techniques for Eliminating Baseband Voice Interference with Telemetry for the Apollo Communication System. By G. D. Arndt, S. W. Novosad, and R. J. Panneto (NASA TR R–337).

CONTRACTOR REPORTS

Testing of High-Emittance Coatings. By R. E. Cleary and C. Ammann (NASA CR–1413).

General-Aviation Pilot Reactions to and Opinions on Groove Runways. By G. E. Cranston (NASA CR–1428).

Research on Metallugical Characteristics and Performance of Materials Used for Sliding Electrical Contacts. By W. H. Abbott and E. S. Bartlett (NASA CR–1447).

Stress Corrosion Cracking of Titanium Alloys at Ambient Temperature in Aqueous Solutions. By T. L. Mackay (NASA CR–1464).

Effects of Sonic Booms and Subsonic Jet Flyover Noise on Skeletal Muscle Tension and a Paced Tracing Task. By J. S. Lukas, D. J. Peeler, and K. D. Dryter (NASA CR–1522).

Appendix 2

NASA SCIENTIFIC AND TECHNICAL PUBLICATIONS

The National Aeronautics and Space Administration makes the results of worldwide research and development activities in aeronautics, space, and supporting disciplines promptly available to all interested parties. NASA's scientific and technical information system now contains nearly one million documents, which are abstracted, indexed, and obtainable through retrieval and dissemination services.

The dissemination services make use of four NASA announcement journals: Scientific and Technical Aerospace Reports, International Aerospace Abstracts, Reliability Abstracts and Technical Reviews, and Computer Program Abstracts. These journals cover the following areas:

Scientific and Technical Aerospace Reports is a comprehensive abstracting and indexing journal covering current worldwide report literature on the science and technology of space and aeronautics. *STAR* is published semimonthly.

By arrangement between NASA and the American Institute of Aeronautics and Astronautics, the AIAA publication *International Aerospace Abstracts* provides parallel coverage of scientific and trade journals, books, and conference papers in the same subject areas as the reports abstracted in *STAR*. *IAA* is published semimonthly.

Reliability Abstracts and Technical Reviews is an abstract and critical analysis service covering published and report literature on reliability. The service is designed to provide information on theory and practice of reliability as applied to aerospace and an objective appraisal of the quality, significance, and applicability of the literature abstracted.

Computer Program Abstracts is an indexed abstract journal listing documented computer programs developed by or for the National Aeronautics and Space Administration, the Department of Defense, and the U.S. Atomic Energy Commission which are offered for sale through the Computer Software Management and Information Center (COSMIC).

NASA also publishes a series of technical journals, reports and special publications. They are:

Technical Reports: Scientific and technical information considered important, complete, and a lasting contribution to existing knowledge.

Technical Notes: Information less broad in scope but nevertheless of importance as a contribution to existing knowledge.

Technical Memorandums: Information receiving limited distribution usually because of the preliminary nature of the data.

Contractor Reports: Scientific and technical information generated under a NASA contract or grant and considered an important contribution to existing knowledge.

Technical Translations: Information published in a foreign language, and needed in the aerospace program.

Special Publications: Information derived from or of value to NASA activities. Publications include conference proceedings,

NOTE

Pages 249-307 have been omitted from this issue.

These pages contain Attachments 10, 11 and 12 of Appendix 1, and are listed on page 73.

Information concerning any of this material may be obtained by writing:

Office of General Counsel, National Aeronautics and Space Administration, Washington, D. C. 20546.

flaws, has been tested in examining indented writing and appears to fulfill unique police requirements. Discussions are currently underway with the Chicago police department, among others, to determine how best to make the instrument broadly available for police use.

A cluster of hanging chains has been shown to reduce wind-induced bending oscillations of tall cylindrical antenna masts. The damping system, developed at the NASA Langley Research Center, consists of chains covered with a flexible plastic or rubber sleeve. They are suspended inside a neoprene shroud from the top of the mast and are completely enclosed by the mast structure. In a particular example, the chain damper, which weighed 12 pounds, increased damping of a 261-pound tower by twenty times. The undamped antenna had a response peak at a wind velocity of five knots, while the damped system at 60 knots showed less vibration than the undamped antenna did at 5 knots.

A subsidiary company has been established by an Illinois firm specifically to make and sell a modified version of a graph scale interpolator. The device, developed at the Langley Research Center, permits rapid and accurate determination of the coordinate points of a graph. The firm is seeking diversification and the NASA-originated device is the first product in its new line.

The Goddard Space Flight Center developed a device to measure accurately the peel strength of composite materials. We know of the following applications: (1) A major metal producer, entering the composite-materials business, used the Goddard concepts to modify and improve its measurement apparatus. (2) A large Eastern company built a unit based on the design, using it to test adhesive bonds. (3) A lumber company in Washington has built a device based on the information for testing the peel strength of aluminum-plywood laminates. (4) A pen manufacturer is using it to test the bond between the metal and plastic shells of its pens.

Goddard research also disclosed that a layer of high-viscosity oil can be added to mercury-pool reflectors that allowed more precise alignment of optical instruments. An engineer from the Wisconsin division of a major equipment manufacturer has adopted this method to certify the straightness of pump shafts that are up to 30 feet in length. The new method eliminates errors that had complicated the assembly sequence and added to production costs.

Analysis of organic materials can be expedited through use of a mass spectrographic analysis system. Spectral data from an unknown sample is compared with the spectra of more than 1500 organic compounds. So versatile is this system that it can be used even when neither the number of components nor their identities is known. The technique was developed in support of NASA's manned spaceflight programs.

A specialized use of contamination control technology is reported by an instrument engineer at an Air Force Missile and Advance Aircraft site. He is using to it to preserve guidance control apparatus, and has found that he can save the Government $20,000 annually by investing about $10,000 in new equipment.

formulations developed under contract for the Marshall Space Flight Center.

A new class of organic polymers have been developed by the Langley Research Center that are exceptionally resistant to heat, light, and radiation. A firm is now experimenting with the polymers as a coating for wire in aircraft service, where its resistance to high temperatures makes it of particular interest. Lewis Research Center has worked out a method for vapor-deposition of the polymers on complex surfaces—such as ball bearings, gears, and springs—that enhances its potential for many industrial applications.

GENERAL

Broad as they are, the foregoing specific categories do not truly reflect the tremendous variety of cases in which NASA-developed technology has had or is having a productive impact upon major fields of American endeavor—in computer applications, for example, or education, or management. The following cases serve to better illustrate this variety: A computer program developed by a NASA contractor is designed to optimize a group of design parameters; it has been requested by over 300 different organizations throughout the U.S. At the Bonneville Dam, for example, engineers used it to optimize the design of control circuitry, while a food manufacturing concern applied it to optimize the variables in food preparation and produce "consistent" foods. The University of North Carolina has adapted the program to medical research and public health, to determine where the available funds should best be spent to improve living standards, education, and health in deprived areas.

A computer program entitled FLOTRAN was developed under contract to the NASA Marshall Space Flight Center to produce flow charts automatically from assorted input statements. Copies of the program were made available, at the cost of reproduction and distribution, to interested inquirers. More than 300 inquiries were received; more than two dozen companies purchased copies of the program.

Several aerospace-related computer programs are available that will facilitate management training. Detailed evaluation of individual and group performance is possible. Similarly, performance of all aspects of project management and development can be measured through the use of "GREMEX," the Goddard Research Engineering Management Exercise.

A major advance in computer-assisted structural analysis will be available to industry as a result of NASA developments in this area. NASTRAN, a major advance in general-purpose analysis encompassing both statics and dynamics, will soon be available at a scant fraction of its multimillion-dollar development cost.

An electronic calorimetric computer has been developed by the Lewis Research Center to calculate nuclear reactor thermal power output to a nominal accuracy of one percent. Personnel at Washington State University had formulated plans to build a similar computer to obtain these same measurements. The University constructed the computer to the NASA design and saved the institution about $24,000.

In the area of public education, secondary benefits of NASA research have been utilized by innovative educators and films in the educational materials market. One of the NASA Centers disseminating scientific and technical information provided an Oklahoma engineer with information that led to the development of a teaching tool which sparked the formation of a new business. The NASA data bank was searched for information on "frequency synthesizers" and the resulting information enabled an engineer to design new equipment. The system has no interconnecting wires, yet for up to 800 students, the teacher monitors each student's answer, total class replies, and the proportion of right answers for the class. The inventor is now negotiating a licensing agreement for national marketing.

Another variety of teaching aid is the series of planetary and solar system models developed and marketed by the Hubbard Scientific Company. This firm, after viewing models developed by the Jet Propulsion Laboratory has created a number of planetary interaction models for use in classroom teaching.

In criminal cases, original incriminating information is often destroyed. The information content, however may have been unwittingly preserved on succeeding pages of a pad or notebook, in the form of so-called indented writing. This evidence frequently cannot be deciphered by the naked eye, so that an improved technique is needed to examine a document that may contain one or more superimposed messages. An instrument developed for the Marshall Space Flight Center, which was originally developed to scan surfaces of components for cracks and

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A high-temperature ferromagnetic material and a fiber-reinforced nickel superalloy. The former is a cobalt-base material with a high-temperature rupture strength and an order of magnitude greater than that of the strongest alloys now used in electric motors and generators to meet magnetic requirements. The other is a composite four times as strong as conventional nickel-base superalloys. It has tungsten fibers enmeshed in its bases, and can be used wherever higher strength or a greater strength-to-density ratio is needed. Examples of such applications include turbine components, such as buckets and vanes, and other parts of advanced electrical power systems.

NASA's study of foam and honeycomb-core sandwich construction has led to an especially interesting innovation in truck bodies. By using plastic-faced foam sandwich panels, the overall weight of a van can be reduced from 45 to 50 percent. This cuts operating costs. Since the panels are prefabricated and new ones can be quickly inserted to replace damaged panels, repair costs are also low. A prototype has been tested for several months, and full production of such truck bodies is expected to begin soon.

Several new textiles and fabrics also have resulted from NASA's material research and development efforts. Outdoorsmen now have blankets that reflect up to 80 percent of the user's body heat, and similar insulation in boots, jackets, and other garments. Another new material can be found now in tents, awnings, window curtains, and bedspreads. It is a breathable and machine-washable fabric produced by vacuum depositing a thing coating of reflective aluminum on nylon or taffeta. The same company producing this fabric sells a lightweight emergency rescue blanket made of aluminized mylar (the material used in the ECHO satellite).

Another company has been formed to manufacture and market undergarments for men and women from a texturized fabric developed originally for astronauts. Although only recently introduced, it has been so successful that the manufacturer expects to produce more ready-to-wear garments, including dresses, skirts, and blouses, from this fabric. Other manufacturers also have been licensed to use the basic fabric.

Coatings and Lubricants

Keeping the equipment necessary for space flights and re-enry into the Earth's atmosphere "smooth and bright" has required the development of numerous new coatings and lubricants—some of which have already solved utterly dissimilar industrial problems.

A manufacturer of gypsum wallboard and other such items, for example, found iron specks from calcining kettles contaminating his products. But a paint developed at the Goddard Space Flight Center met the requirements for coating the kettles and saved this manufacturer several thousand dollars. A firm now plans to test this paint in a tube mill where it will be subjected to sulfuric acid at 1300° F. Another company credits Marshall Space Flight Center work with "a very important educational role in the development of a new proprietary coating method" that has made possible the development of a new line of ablative thermocouples. This coating was first developed to protect parts of the Saturn booster's base from the engine exhaust.

The information that another concern obtained about materials from NASA's files enabled it to develop a shielding technique to improve a plasma jet spraying process. This is used to coat parts of valves and other devices with corrosion and wear resistant alloys. Tests thus far have been so promising that the company has purchased and is installing machinery to manufacture valves by this new process.

Solid lubricants are preferred to greases and oils in food-processing and textile machinery, but standard dry lubricants have often worn through and failed. Lewis Research Center developed a composite self-lubricating bearing surface made by means of powdered metallurgy to overcome this difficulty. The same center developed a ceramic-bonded dry lubricant for the rotating seal of a pump for liquid fluoride propellants under vacuum at high temperatures—and bearings coated with this lubricant are on the market now.

A copper-acrylic enamel developed by the Argonne National Laboratory, and called to potential users' attention by a NASA-AEC Tech Brief, is serving already as a lubricant in the cold drawing of refractory metal tubing. Sprayed on, it prevents seizure and surface defects, and is effective for several drawings through a dye.

Another company has tested a new solid lubricant in metal-forming operations with an eye to manufacturing and merchandising the lubricant. It is one of five

now being used by NAPCA to assess the correlation between various pollutants and automobile accidents to arrive at safety limits of contamination.

One of NAPCA's major responsibilities is to develop instrumentation for continuous monitoring of a wide variety of pollutants in urban environments so that control measures can be initiated when concentrations of certain contaminants exceed what are considered maximum safe values. To meet NASA's requirements to monitor contaminants in closed-cycle life-support systems, the Marshall Space Flight Center has developed small, inexpensive, mass spectrometers which permit automatic analysis of contaminants. Engineers at NASA and NAPCA are currently evaluating the MSFC instrumentation and techniques to determine their suitability for automatic monitoring of pollutants in the atmoshphere.

Safety Devices and Techniques

A number of important applications of NASA-developed technology have occurred in several fields related to human safety: many firemen are killed or injured each year by smoke inhalation. Present protective breathing masks are based on technology that is more than 25 years old and is generally considered inadequate. Fire departments in the U.S. require a breathing device which is economical, nonbulky, lightweight (10 pounds or less), and has a self-contained or self-generating air supply that will last at least 30 minutes under actual fire-fighting conditions. Among several potential solutions to this problem suggested by aerospace technology (e.g., use of sodium superoxides), one that appears most promising is based on the Apollo Portable Environmental Control System (PECS) which uses a sodium chlorate candle as an air supply. A report on the PECS system has been reviewed by fire-department heads in Boston, Chicago, New York, and Los Angeles, all of whom feel that the proposed system would meet their needs. Steps are now being taken by NASA, in cooperation with these fire departments, to design and build two prototype units for demonstrations to the fire-fighting community.

Poorly ventilated areas of coal mines are potential pockets for accumulation of explosive gas. However, there are currently no suitable instruments for accurate measurement of low airflow velocities. A sensor developed by the Electronics Research Center as an airspeed indicator for VTOL aircraft during critical low-speed maneuvers was recently demonstrated to the U.S. Bureau of Mines and was regarded as having significant potential for making the required measurements. The Bureau is now considering funding the development of a portable version of this sensor for use in coal mines.

Under suitable conditions, coal dust can initiate mine explosions and can help spread methane gas explosions over wide areas in a mine, thus increasing their severity. In addition, coal dust is a major cause of "black lung" disease. New standards being imposed on industry to achieve lower levels of coal-dust concentrations in mine atmospheres require a monitoring capability beyond that of current methods. A compact, lightweight dust monitor developed by NASA for the Apollo spacecraft will permit coal-dust measurements at much greater accuracy and much more rapidly than is possible using current methods. The NASA instrument is being tested by the U.S. Bureau of Mines with a view toward modifying it for specific mining applications.

An electronics manufacturer is marketing a special rescue light that was originally developed for NASA, the Air Force, and the Navy. The device, a high-intensity flashing light, can be seen from a distance of 10 to 20 miles, depending upon visibility and altitude. Flashes can also be seen under water and through waves and fog. The device has reportedly saved many lives, both military and civilian.

At the Mississippi Test Facility, a NASA contractor improved the design of an orthopedic stretcher. This was done so that a workman could be removed if necessary from a large deep tank with an access hole only 18 inches wide. The stretcher is a "scissors" device that can be slipped under an injured person and hold him in traction while he is being lifted through the hole. This stretcher has now been licensed for manufacture.

IMPROVED MATERIALS

Without a great many new synthetic materials it would have been impossible to land men and instruments on the Moon. NASA's efforts have, in turn, contributed to the recent surge in materials science and engineering. When the magazine *Industrial Research* chose the most significant new technical products of 1968, two were superalloys from the Lewis Research Center:

application techniques developed to serve NASA test pilots have led to improved procedures in muscle rehabilitation, too.

One of the most frequent causes of death for paraplegic is loss of voluntary control of the urinary function. This leads to tissue deterioration, infection, and kidney damage. In the Bowman Gray School of Medicine at Wake Forest University, a researcher concluded that the best solution would be a reliable, totally implantable, valve that the patient could easily control. A Lewis Research Center engineer suggested a valve design based on one used for manometer tubes. It can be controlled by pressure, and remains open if it fails to function. This valve system now has been re-engineered, and a prototype is being tested preparatory to implantation.

For Surgery and Therapy

One of the most dramatic innovations in medicine resulting from the space effort is the use of a computer to improve X-ray pictures. An enhancement technique developed by the Jet Propulsion Laboratory to correct photometric, geometric, and frequency response distortions in pictures transmitted to Earth from the Moon and Mars is equally applicable to other images. JPL has received a grant from the Department of Health, Education and Welfare to continue work on the medical applications of this technique. It is a digital process in which particular details of interest to a diagnostician, therapist, or surgeon can be made more clearly visible. The stereophotogrammetric technology used in lunar mapping also has been used in morphological studies of the human body.

At a New York hospital a doctor now uses a microthermocouple probe in cryosurgery for patients with dystonia, Parkinson's disease, and other aliments causing abnormal muscular motion. In a Boston hospital two doctors use an identical instrument to repair lesions of the eye by "welding" tissue at cryogenic temperatures. This probe was developed originally under contract to the Lewis Research Center and is now on the market.

When specimens of tissue must be taken from a patient's inner ear for examination, the outer bony structure must be removed first. Chipping away and dissolving bone is difficult and time-consuming. From NASA a University of Kansas Medical Center investigator learned about a special air-abrasive device, tried the instrument, and found that it made the removal of bone much easier and quicker.

A miniature radiation dosimeter developed for NASA is helping to increase the precision and safety with which therapeutic radiation is delivered to patients. Lewis Research Center also has helped to reduce the hazards of treating patients with radioactive iodine. By substituting a different isotone for the one used previously, it has been found that the dosage can be reduced by a factor of nearly 10,000.

HEALTH AND SAFETY

Measurement of Air Pollution

National concern with techniques of measuring and controlling sources of air pollution led to the publication of NASA survey on "Air Pollution Monitoring Instrumentation", which is now in its second printing at the Government Printing Office. Although the equipment described in the survey was designed to satisfy such NASA requirements as the control of contamination in spacecraft and aircraft cabins, the instruments developed for this purpose have many other applications in science, industry, and government—from hospitals concerned with airborne contamination in operating rooms to Federal and municipal agencies charged with environmental protection. Among specific examples: airborne particulates (minute fragments of solid materials) from a wide variety of natural and industrial processes represent a major source of air pollution problems. For this control, the National Air Pollution Control Administration (NAPCA) requires instrumentation to measure both the concentrations and sizes of particulates in the air itself and in the waste products from industrial plants. A system developed by the Lewis Research Center for generating air streams carrying very precisely controlled particle sizes and concentrations is currently being evaluated by NAPCA to determine how it can assist in air pollution control.

Carbon monoxide, ozone, nitrogen oxide, and other air pollutants adversely affect the performance of automobile drivers in a way which is believed to contribute substantially to the U.S. highway accident rate. A complex coordination tester developed at NASA's Langley Research Center for determining how astronauts' performance suffers in stressful and contaminated environments is

When a child has been severely burned, his condition may be monitored by noting biochemical changes in the respiratory tract, but this should be done without touching the child's body or connecting tubes to his throat because of the air restriction and pain involved. Investigators of this challenge in the Shriners Burn Institute at the University of Texas found that a respirometer developed at the Ames Research Center could meet such requirements, and a prototype is being made available for evaluation.

At the University of Wisconsin, an endocrinologist wanted an implantable instrument to measure small temperature changes of internal organs and cavities in a monkey. A search of NASA literature for him turned up a small temperature telemetry system developed by the Ames Research Center that could be implanted in the animal without adverse reactions. It transmits signals to a standard FM receiver, and has recently been commercialized. The Wisconsin researcher has obtained two such units, and has had one implanted satisfactorily in a monkey for more than three months.

Aids to Cardiology

A telemetry unit for electrocardiograms (EKGs) that a contractor produced for the Ames Research Center has been modified slightly for use in a hospital's intensive care ward. Heretofore, a heart patient had to lie still, encumbered by lead wires, to be observed continuously. Information obtained while a patient is exercising is often more significant than can be obtained while he is sedentary. The telemetry unit designed for astronauts solved this problem, and the hospital system permits a patient to move freely within 100 feet of the receiver while his EKG is being recorded.

A Duke University Medical Center researcher who wanted to measure heart action more precisely than is customary also found NASA knowhow helpful. Electrical signals result from the heart's action, and this investigator wanted to measure them simultaneously at 15 points with a device that would not result in heart-wall damage upon insertion. An instrument engineer designed a 15-electrode probe within an ordinary hypodermic needle for him under NASA sponsorship, and this new aid to research is now in use.

National Institutes of Health officials have identified numerous NASA engineering advances that have contributed to the artificial heart development program. Both basic cardiovascular research and acute clinical cardiology have also benefitted in numerous ways: Sensitive pressure transducers developed for aerospace work are helping researchers measure intravascular and intracardiac pressure. Impedance cardiography, ultrasonics, and sterophotogrammetry are aiding diagonisticians. Implantable electrodes and a new pacemaker electrode made out of an aerospace allow will soon be available.

Physicians often wish to know the output of blood pumped by the heart. A device called the four-electrode impedance plethysmograph, developed for the Manned Spacecraft Center, permits a doctor to learn this without injecting a hazardous foreign substance into the body. The electrode circuity enables the doctor to note changes with time, and the rate of changes, in the volume of the blood pumped. Such data provide early warning signals of conditions requiring corrective action.

Aids to Bodily Activity

"Space underwear" and control apparatus produced to regulate the astronauts' body temperature has proven extremely helpful in medical research. At the University of Washington cardiologists studying the effects of exercise and heat on the heart needed a means of increasing a person's skin temperature without interfering with his bodily movement. They borrowed and used space underwear successfully. Similar undergarments were used at the Rancho Los Amigos Hospital to cool the skin of handicapped persons without restricting their movement.

At the Goldwater Memorial Hospital in the New York University Medical Center, a patient now wears pants from a pressurized "G-Suit" to move about on crutches. This patient's hip joint is fused so that she can only stand or lie down. She is also suffering from orthostatic hypotension, a condition characterized by lowering of blood pressure upon assumption of an erect position. The pressurized garment is a means of combating this orthostatic hypotension.

Ambulatory rehabilitation of handicapped persons has been advanced by the use of simulators developed to prepare astronauts for the effects of lunar gravity. A major rehabilitation center is now using a modification of a sling support developed at the Langley Research Center to train astronauts. Electrode

MEDICAL APPLICATIONS

The advances in medicine that are ascribable in part to the space program are now coming into use. Few foresaw how extensively the same skills data, and devices that were needed for ventures into space could be employed to prolong life on Earth. Now both physicians and surgeons are using by-products of the space effort to combat menaces to people's health and happiness.

So, too, are many researchers in the biological laboratories of hospitals, universities, pharmaceutical and other private companies, and numerous government agencies. Recent developments to which NASA has contributed have made it much easier than ever before to control contamination, monitor physiological phenomena, and rehabilitate handicapped persons.

Contamination Control

The reliability and precision demanded for manned space flight required extreme cleanliness in shops and factories where little thought had been given to contaminants previously. Throughout industry now, one finds electronic parts, ball bearings, and other components of delicate devices being produced in "clean rooms" that are several times as immaculate as conventional hospital operating rooms were a few decades ago. NASA's "Contamination Control Handbook" describes how such ultra-cleanliness has been attained.

One important development is the laminar flow clean room in which filtered air is moved horizontally at rates that prevent particles from settling out of it. This type of clean room is rapidly coming into use in both manufacturing plants and hospitals. It can reduce drastically the number of microbial organisms than can fall into an open wound of a patient on an operating table. In one installation, a careful study found that there were only 2.4 microorganisms per 100 cubic feet of air in the area next to a wound, compared to as many as 230 in an older type of operating room. Since fewer particles can reach an exposed wound, there is less need for gowning and draping doctors, nurses, and other attendants elaborately, and this makes their work easier without imperiling patients.

The drugs used to treat certain types of cancer weaken the patient's resistance to various infections, and a transportable laminar flow clean room has been built for such patients. It protects an occupant from the outside environment and thus enhances his chances for recovery.

Hospitals also have shown interest in a particle counter developed for the Marshall Space Center to monitor air purity in industrial clean rooms. This counter may be useful both in operating rooms and in intensive care wards.

NASA contamination monitoring and control techniques are even helping to hold down the cost of medical care. The director of laboratories at a suburban Chicago hospital has estimated that such techniques have saved hospitals 1000 manhours of work and at least $100,000 in 1969. This year he expects the savings to be nearer 2000 manhours and $150,000.

A single drug company, NASA researchers were told, has saved $3,000,000 a year by improvements, in methods of preventing contamination of processes and products. The saving achieved in testing done to assure sterility and compliances with national standards was especially impressive. If, when a sample is taken for testing, airborne bacteria settle on a culture plate, the result is a "false positive" test. This company reported that the use of the laminar air flow technique at the bench level had essentially eliminated costly false positives in its testing procedures. A number of drug companies use this new technology today.

Physiological Monitoring

Many of the devices and systems developed to observe the activities of astronauts and the behavior of distant spacecraft have also proven useful in routine medical practice. At least four large companies are now marketing medical monitoring instruments that they recognize and promote as results of NASA's work.

When a hospitalized patient begins to recover and move about a ward, it often becomes difficult to keep a constant check on his condition. A system of transmitting medical data by radio from such a patient to a nurse or physican would grant him freedom of movement, yet keep him under observation. Researchers at the Northwest Handicapped Center asked if such a system was feasible within a hospital, and learned from NASA's experience that it was not only feasible but could be set up with commercial equipment. The system that resulted has been tested and found satisfactory.

A strain gauge transducer developed by the Goddard Space Flight Center is being used by a major drug manufacturer for physiological monitoring. The manufacturer's laboratory plans to use this transducer for monitoring physiological responses to therapeutic chemicals. The transducer will be implanted in animals to monitor muscle activity, blood pressure, and biological responses to chemicals.

A government installation is building an X-ray radiation detector device based on information originated by the Goddard Space Flight Center and announced in a NASA Tech Brief.

A major West Coast aerospace corporation is currently preparing to market a portable instrument for measuring extremely small electrical resistances (microohms). This instrument has been made possible by the adaptation of subminiature circuits reported in Ames Research Center Tech Briefs.

A compact water-cooled mount for commercial miniature pressure transducers developed by the Lewis Research Center allows installation of the transducers in hotter (over 1000°F.) areas than was previously possible. The result is a significant improvement in pressure-sensing capabilities. A manufacturer of miniature pressure transducers learned of this NASA development and is planning commercial manufacture of the water-cooled mounting.

A contractor for the Lewis Research Center developed a closed-loop temperature controller having higher sensitivity, reliability, and power capacity than commercially available units. With a different sensing element, the device can also be used as a low-pressure controller. As a low-pressure controller, it is directy applicable to many automation systems where low-pressure processing requires critical control of fluid feed pressures. The company that developed the controller has included the device in their product line as a solid-state temperature switch.

An ultrasonic temperature-measuring device has been incoroprated in the product line of a company which developed the device under contract to NASA. This device determines temperature by measuring the transit time of an acoustic (sound) pulse in a wire sensor or probe inserted into the test environment. It operates on the principle that the speed of sound in a sensor material is a function of temperature. The device can function in the extremely high temperatures in the core of a nuclear rocket engine. Unlike thermocouples, no electrical insulation is needed, and the probe can be chosen from a wide range of suitable alloys. It is resistant to shock and vibration, can tolerate high pressures and substantial excess temperatures, and is not limited by part geometry.

Transducers developed for the Manned Spacecraft Center to measure the impact of the Apollo Command Module during water landings are being used in the fitting of artificial limbs. The transducer is smaller than a dime, weighs less than an ounce, with sensing diaphragm of stainless steel. The waterproof unit is not affected by temperatures between freezing and 120°F.

A new commercial transducer for measuring temperature differential between the inlet and outlet flow of water coolant in electric arc research has resulted from a NASA program. The transducer, especially effective in measuring temperature in strong electric and magnetic fields, is applicable to the chemical process industry, nuclear reactor technology, and internal combustion engine testing, and in other specialized high temperature work. A new company has been formed to market the device.

A torque meter was developed for Marshall Space Flight Center to simulate the characteristics of hysteresis in motor rings under dynamic conditions. The simulation avoids the expense of actually making and testing a complete motor. One electronics company saved $10,000 in production of a low cost, high volume military product. The technique also enabled the same company to produce another product more economically.

A meteorological photo receiver developed for the Goddard Space Flight Center is now being sold commercially. The instrument provides reception of a series of fifteen cloud cover pictures per day from meteorological satellites for weather forecasting. Its maker has sold a number of the units at prices ranging between $5,000 and $10,000 each.

Spacecraft, Inc. of Houston, Texas is manufacturing for sale a Bit Error Rate Detector originally developed for Goddard Space Flight Center. The detector is used to test the performance of magnetic tape recorders to detect malfunctions. Several instruments and accessories have been sold at a price of approximately $12,000.

transmission. An electronics firm used the NASA Tech Brief announcing the innovation to build a product incorporating 16 signal generators channeled into one output by random rather than slower sequential scan, with the scan being handled as in the multiplexer. The company expects to market 20 to 30 units per year at about $3,000 per unit.

A company has incorporated in its special laboratory refrigeration unit (which cools to 4 degrees K) an automatic thermal switch developed at Jet Propulsion Laboratory. The firm has obtained from NASA a nonexclusive, royalty-free license to use the invention.

Fluid Control Systems

Application of the principles of fluid dynamics in control systems results in a reliable and efficient means for controlling a wide variety of instruments and machinery. This new technical knowledge has been put to profitable use by industrial concerns, among which the following may be cited as examples:

A machine-tool manufacturer, using information received from Lewis Research Center, designed and is now manufacturing a line of fluid-controlled automatic turret lathes. More than 50 such machines have been sold at a price of approximately $300,000 each, and the company is enthusiastic over future sales prospects for this specialized line of turret lathes.

A large paper company with headquarters in Pennsylvania has designed a fluidic oscillator, one of which is planned for use with each of its 30 drying hoods to measure moisture in recirculating air that passes under the hoods in the paper-drying process. The fluidic oscillator permits accurate measurement of humidity, making it possible to reduce fuel consumption by 5 percent, approximately $63,000 per year. Material cost is estimated at $1,000 per unit.

Frequent failures of specialized ship-control systems has led a large shipyard to investigate fluidics as a more reliable principle around which to design new on-board systems.

Another technologically oriented firm, working from NASA research, is incorporating the principles of fluidics in the design of tools for mining, tunneling, and metal-working industries.

Welding

Manufacturing large space boosters required extensive research in joining metals. NASA's contributions to the field of welding have been particularly significant in advancements in electron beam, inert gas shielded, and laser welding methods. The information from the various NASA research programs in these fields has been broadly disseminated to industry through various NASA publications. A handbook for "Workmanship Standards for Fusion Welding" developed by the Space Nuclear Propulsion Office has been used extensively in industry as a quality standard.

COMSAT is using inert-gas welding technology developed by Marshall Space Flight Center in its new engineering manufacturing laboratory. A welding alignment tool originally developed at the Manned Spacecraft Center is now being manufactured and sold by a large supplier of welding tools and equipment.

Tack welding has often been used in the alignment of large workpieces in preparation for final welding. A new approach uses a number of clamps to hold the workpieces in true alignment by means of a thin steel band placed through the joint to be welded and held in tension. These clamps may be adjusted over a large tension range and do not interefer with the welding procedures since each clamp is removed just before the weld machine reaches it. A firm is manufacturing the clamp under a NASA license.

Sensors and Detectors

The space program requires the use of many sensors and detectors in both the manufacturing and operation of space vehicles. NASA has made a major contribution in the field of sensors for both ground and airborne applications. This technology is being used extensively by many industrial firms as well as other government agencies. Two companies are presently applying NASA experience documented in a Marshall Space Flight Center Tech Brief entitled, "Detection and Location of Metallic Objects Embedded in Non-Metallic Structures." One company uses the detector to assist surveyors in locating buried metallic boundary stakes, and another corporation is using the detection device to locate semiconductor devices in potting compound mediums within large assemblies. Considerable cost savings are estimated in the latter case, since large amounts of potting compound would have to be removed to locate a faulty semiconductor.

A solid state recoverable fuse developed at the Goddard Space Flight Center has resulted in a number of new or improved products now on the market. The Goddard innovation protects electronic circuits during overload conditions, and permits them to function immediately after the overload is removed. An aerospace company has successfully developed a switch based on the NASA work. A company in Maryland has increased the sales of one product by using this technology. An Ohio electronics manufacturer uses the solid-state recoverable fuse in several of its electronic control units. (The advantages of potting a recoverable solid-state fuse with other electronic components are that it eliminates external connections for fusing, and prevents possible explosion and environmental hazards to the electronic control unit.) The latter company alone expects an increase in sales volume of approximately $2 million over the next five-year period.

A small California manufacturer of computer memory cores has used NASA information to modify its production processes and develop an improved product. The innovation in memory-core design makes possible completely automatic production processes. The company estimates that the improved production technique will yield a 25- to 30-percent cost reduction. Two other firms have evaluated the information and used it as background in the design of new memory word line configurations.

A simple method of eliminating registration errors in the production of two-sided printed circuit boards was reported by a Langley Research Center contractor. (Obtaining accurate correspondence between the photographic prints of two sides of the board is a common problem in the manufacture of two-sided boards.) Three firms that have used the technique have reported that it has reduced errors and improved production efficiency. One firm noted that accuracy has been increased, and drafting and layout time have been reduced by 50 percent.

Conventional test procedures for integrated circuits do not measure the electrical characteristics of individual circuit elements because the elements are not usually accessible. Several commercial firms have developed methods, based on a Goddard Space Flight Center external pin-to-pin testing procedure, which allows examination of individual element performance. A temperature-regulator manufacturer who used integrated circuits expects extensive use of this technique.

A related development at Marshall Space Flight Center for in-place checkout of semiconductor devices without disturbance to any circuitry has been successfully applied by another firm. They report appreciable reductions in technicians' time and component or circuit damage.

Work done for the Jet Propulsion Laboratory has led to two new products introduced by a small manufacturer of microwave components. The first device, a cold-noise source, provides an accurately known input noise temperature for use in measurement and calibration of microwave equipment. Sales of this new product are reported as about 10 percent of total company sales. A second product, an insertion loss test set, allows very accurate measurement of losses due to insertion of microwave components into a circuit. This instrument is important to the development of accurate cryogenic terminations. The basic technology is covered by a NASA-owned patent, and the company has already sold a number of instruments.

NASA integrated packaging for electronic equipment, developed by Jet Propulsion Laboratory, has been successfully used by at least two firms. Sales of such an "integrated package" product by one manufacturer are at least $1 million annually, and the marketing director has estimated that during the next three to four years sales will increase to $10 to $20 million annually.

Marshall Space Flight Center has designed a simple, handheld lead-bending tool for forming the leads of electronic components to fit precisely in the holes of printed-circuit boards. A manufacturer has obtained rights to use of the patented item and has modified the tool to provide lead cutting as well. A bench-mounted model has been designed to operate with a foot switch, leaving the operator's hands free.

Flat conductor cable, under investigation for more than ten years, has reached a highly successful stage of development. These cable forms offer advantages to electrical-system designers by saving weight, space, cost, and lead time with excellent reliability and uniformity. A large family of tools, fixtures, and test equipment has evolved for flat-cable preparation, installation, and repair.

A Marshall Space Flight Center contractor designed a multiplexer to sample repetitively up to 234 data lines and timeshare them selectively for single-line

ported: "Without the information, it could have taken at least an additional year's work of an engineer at a cost of perhaps $15,000. But the main advantage is that we will have our new product in six months instead of two years. Since this product has an anticipated future sales of $100,000 per year . . . we could be ahead by as much as $200,000 in projected sales."

Frequent quality-control failures in the production of nickel-cadmium batteries led one manufacturer to develop more effective testing equipment and battery-conditioning procedures. Company engineers incorporated into their test equipment a battery recharge unit developed originally for the Goddard Space Flight Center. The remodeled unit has increased reliability and reduced warranty claims.

The switching of inductively loaded circuits often causes interference in adjacent electronic equipment. Marshall Space Flight Center has evaluated various arc-suppression methods to facilitate straightforward and consistent circuits design for suppressing interference in adjacent electrical circuits, such as computer equipment. Previously cut-and-dry methods, often laborious, had been the only practical approach. A number of companies are applying the information on arc suppression to product design with the major benefit being higher quality in newly designed products. An executive in a Michigan firm estimated that the NASA-developed data saved the company $50,000. He had been seeking the most effective suppression technique for a 60-volt coil in a high-speed printer. He commented that the document ". . . allowed me to make a correct decision when an incorrect evaluation was being suggested . . . This information is very solid and showed results that I would not have expected."

A small manufacturer of electronic equipment reports that information relating to a specialized multivibrator at the Goddard Space Flight Center was the impetus for the development of a new industrial product. NASA technology provided significant savings to the company, which expects to sell several hundred of the specialized multivibrators each year.

An Ames Research Center development has aided many biomedical researchers investigating bioelectric potentials of the human cell. Medical researchers at a major university are using an Ames-designed miniature electrometer preamplifier in conjunction with intracellular microelectrodes to investigate the electrical properties of cellular membranes. The NASA design is considered uniquely valuable because of its small size and specialized circuitry. Investigators at the Brain Research Center at another university are using the Ames device to isolate, measure, and monitor individual brain cells. A major northeast institute of technology is using four of the preamplifiers in cell research.

In the field of medical electronics, NASA-developed telemetry systems have found widespread application. Combinations of sensing devices and advanced electronics have provided means of telemetering medical information from moving humans and animals without contact and without interference with normal activities. Since the original development work at the Ames Research Center, commercial versions of the device have become available from several sources. One design for implantation will operate for more than 5,000 hours on its self-contained battery. The units have been applied for telemetering blood pressure, electrocardiograms, electroencephalograms, impedance pneumograms, and electromyograms. A miniature telemetry system is helping researchers to determine where tooth damage will occur because of pressure-induced stress.

The miniature television camera developed to observe Saturn stage separation during the Apollo flights measures 4 by 3 by 1.5 inches, weighs 16 ounces, and is battery powered. Several versions of the miniature camera are now on the commercial market, finding medical, oceanographic, and industrial uses.

A professional investigator and security consultant in California developed and built an automatic security monitoring and warning system with the aid of NASA information. Reported savings due to the NASA information are approximately $10,000.

The New York laboratory of a large firm has incorporated three NASA-developed electronic circuits in an ultrasonic testing system it designed for its own use. All three circuits were developed at the Goddard Space Flight Center.

A new company has been formed to manufacture energy storage capacitors. The underlying technology was necessitated by Lewis Research Center requirements relating to low-impedance pulse lines for use with plasma accelerators for space propulsion. This technology allowed the new firm to enter a market not served by the major companies in the capacitor field. The company has expanded its product line, and today employs more than 150 people.

intends to use design features of this device to develop a router to cut in-service stainless steel nuclear reactor pipe.

A methods engineer was able to reduce training time, and gain worker acceptance for numerically controlled machine tools, by means of a manual tape reader developed for Kennedy Space Center. The device lets the user interpret the punched holes in paper tape. Operators now feel they "understand" the tape, and production from the numerically controlled equipment is now more nearly as projected. Based on this experience, the company has ordered additional tape-controlled equipment.

An improved punch and die set was developed under a NASA Lewis Research Center contract for fabrication of Centaur vehicles and support equipment. This tool has the advantage of producing tubing flares that are dimensionally more accurate and stronger than those made with conventional tools, providing tighter tubing connections. Subsequently, a company developed with its own funds a machine incorporating the punch and die. A. U.S. Patent (3,411,338) was obtained for the machine and a license for its manufacture has been granted.

A NASA contractor has devised an analytical technique that permits comparison of alternate mechanical designs for reliability. This technique has been employed by a manufacturer of mining equipment. conveyor systems, and cargo-handling gear such as winches, lifts, and cranes. Under contract to a Mississippi shipbuilder, the company was able to provide valid data on systems reliability and maintainability.

A shipbuilding company has had severe problems with the buckling of decks and other distortions caused by the heat of welding and hand hammering. By a loan arrangement with the Maritime Administration, the company obtained an electromagnetic hammer developed at the Marshall Space Flight Center. The hammer is being evaluated for rapid removal of distortions while keeping the metal free of the stresses caused by hand hammering.

An electrical machinery manufacturer, in the development of a new product, faced a stumbling block in devising a satisfactory mounting method. A NASA development that the firm modified solved the problem. The Jet Propulsion Laboratory had developed a special leaf-spring suspension providing accurate parallel displacements. The company estimates the data saved fully $2,000 in professional manpower that would have been required to solve the problem.

A joining process developed for preparing highly accurate, hollow, spherical rotors has been applied to other types of joints by an electronics company. The method was developed under a Jet Propulsion Laboratory contract to make highly precise spheres. Efforts to join the hemispheres by brazing or welding caused excessive distortion. In the new process, an undersize insert closes the gap. The joint is filled by electroplating metal into the area, and then machining away the excess. Since the process is carried out at room temperature, there is little chance for thermal distortion. The NASA process was sufficiently effective that it has been incorporated into the plant's regular manufacturing procedures.

The NASA "Contamination Control Handbook" (mentioned later in connection with medical applications of aerospace technology) has aroused interest in a wide variety of industries as well as in hospitals and laboratories. A small ceramics manufacturer in Ohio found the handbook helpful in the production of a new product. In this instance, the need was not for complete clean room technology, but rather the elimination of contaminants which would otherwise interfere with the quality of an electrically fused silica. The company not only reported that the use of the handbook saved time in improving production, but also eliminated the necessity for going to outside consultants.

The Ames Research Center developed a small, specialized, metal bending device. A St. Louis manufacturer of metal doors heard of the device, scaled up the size of the unit, and adapted it to its own operations. It permitted elimination of two previously performed bending operations, resulting in a significant annual saving.

Electronic Circuits

NASA-developed technology in electronics has been transferred to broad segments of industry, in applications that range from specific circuits to complete communications and telemetry systems.

A small midwestern manufacturer obtained from the Small Business Administration, through a NASA-sponsored Regional Dissemination Center, a group of thirteen reports describing the state-of-the-art in temperature-compensated crystal oscillators. Through these reports he was able to improve his existing products, and to have ready within six months two new product lines. He re-

increased image brightness and high sensitivity to contrast. A subsidiary of a large California aerospace firm has borrowed test equipment and is evaluating this NDT technique for location and placement of nuclear reactor fuel cores. If successful in reducing reactor fuel-component rejections, the cost savings could be substantial.

A major U.S. producer of zirconium, columbium, and tantalum is using a non-destructive test method for identifying metals that was developed for the NASA Manned Spacecraft Center. High-purity zirconium is required for cladding fuel and nuclear reactors. Chemical and metallurgical processing cycles to produce high-purity zirconium create large amounts of scrap which is returned by customers and re-refined. But scrap material, before recycling, must be sorted. The NASA-developed test method, which involves a specialized measurement of the characteristic potential differences between a reference electrode and the test metal, has replaced expensive chemical qualitative tests formerly used.

Liquid crystal non-destructive testing methods developed by the Lewis Research Center are to be used by a large Maryland firm to monitor the quality of wallboard during production. Previously there has been no satisfactory method for the non-destructive determination of the frequency and distribution of voids within wallboard. A NASA development, originally applied to the testing of fiberglass laminates, promises an answer to the problem. A temperature-sensitive crystal solution is applied to the wallboard, which is then heated from the opposite side. Changes in color signal the location and size of any voids. The manufacturer anticipates higher quality of wallboard at lower production costs.

A major industrial firm has evaluated the impact on it of NASA-disseminated information on non-destructive testing. The company estimates that it saves about $1 million annually because it can safety use materials at a higher proportion of their true strength.

At least three companies have adapted a NASA-developed technique for testing tensile yield strengths that uses a smaller number of specimens, reducing inspection time and costs. This heat-treatment testing method, developed under contract to the Space Nuclear Propulsion Office, has yielded significant aggregate savings to these companies.

Manufacturing Techniques

Air bearings used in precision guidance and control systems require extremely smooth surfaces. Hard-anodized aluminum laps, developed at Marshall Space Flight Center, have produced scratch-free surface finishes on beryllium four times finer than previously attainable. They can be used repeatedly with a fraction of the wear experienced with conventional laps made from cast iron, brass, and granite. These long-life laps are now commercially available for either bore or flat-surface lapping.

An explosively actuated tube swager developed at Langley Research Center may find broad use in industry. The device joins tubing by bounding an exterior metal sleeve to each end. The swager is actuated by the energy from a .22 caliber blank cartridge, and is fast and simple to use. The resulting joint is impervious to liquids and gases, and resists damage from vibration. After firing, a groove is visible in the outer sleeve if a sound joint has been made, providing a quick check of the joint quality. The device is now being manufactured commercially.

An Oklahoma petroleum company wanted to avoid a time-consuming sample collection and analysis process by using on-line refractometers in process control. However, the idea was held back for want of a proper dynamic seal. An employee of the firm noted a reference in an engineering magazine to a vented piston seal developed at Jet Propulsion Laboratory. The company obtained additional information from JPL, modified the seal slightly, incorporated it into the system, and reports that "the device has been of great value."

A Michigan company is now manufacturing and selling portable tools for brazing tubing in areas of limited access. The design was developed under a NASA contract. The company has invested a substantial amount of its own funds to develop the tools and has recently proposed the use of the tools of airlines for jet-engine maintenance. Substantial sales in this area are expected. These tools include a hand-held device for cleaning the exterior surface of a tube, a cutting tool, a deburring tool, and a tool for removing brazed unions.

A company under contract to Marshall Space Flight Center has developed a lightweight, portable router that can machine heavy subassemblies in place. It has a variable-speed drive and is capable of making cuts while following more than one contour. Newport News Shipbuilding and Dry Dock Company

Appendix 1, Attachment 9

EXAMPLES OF TECHNOLOGY TRANSFERS

MANUFACTURING PROCESSES

Non-Destructive Testing

NASA has made substantial advances in the development of various techniques for non-destructive testing (NDT). NASA developments in such areas as electron and neutron radiography, liquid crystal testing, ultrasonic testing, and eddy-current testing have found many uses in industry for product improvement and quality control. Examples include: An improved solid-state radiographic image amplifier was developed under contract to the Marshall Space Flight Center for direct viewing of radiographic images, in place of fluoroscopy and photofluoroscopy. Electronic radiography is superior to both methods because of

NOTE

Pages 317-353 have been omitted from this issue.

These pages contain Appendix 4.

Information concerning any of this material may be obtained by writing:

Office of University Affairs, National Aeronautics and Space Administration, Washington, D.C. 20546

Appendix 5

PUBLIC INTEREST IN THE SPACE PROGRAM

The space program has engendered almost incalculable interest on the part of the general public. It is "incalculable" because measurements cannot be precise, but there are some so vividly demonstrable as to leave little doubt that the interest is as great, perhaps, as there has been in any single effort in this Nation's history.

Last summer more Americans—and, indeed, people throughout the world—followed closely the manned lunar landing than any event in history. Worldwide the figure reaches almost 1 billion who heard or saw the event itself through a worldwide satellite communication network. A large percentage read something about it, or heard a speaker, or saw an exhibit, or purchases something (a stamp, a book, a recording) about it.

In NASA we do not translate *interest in* as *support for.* We only acknowledge the interest and try to supply goods and services on a reactive basis. And it is extremely important to appreciate the fact that these goods and services are factual, not self-serving and not message-bearing.

Interest today is at its highest peak in the 11-year history of the space program. The figures below are for calendar year 1969, but the trend in January, February and March is higher than the highest months of last year.

It is an interesting fact that while the Appolo program has created the greatest amount of interest, the total public reaction appears almost equally divided between the Apollo program and a combination of all other programs—an almost even 50/50 split.

Public Mail

	Amount
(*a*) In calendar 1969, general inquiries numbered	485, 300
(*b*) Mail directed to the astronauts numbered an additional	483, 530
Total public inquiry mail	968, 830
(*c*) In (*a*) above, mail from the educational community (students and teachers) was	205, 100
(*d*) In (*a*) above, mail from foreign source was	68, 000

Publications

In response to requests during calendar year 1969, NASA distributed free publications totalling about	5, 000, 000
Incomplete reports on 53 titles of NASA publications (42 non-Apollo) show that the Superintendent of Documents, GPO, has sold copies totalling over	500, 000
In little more than 6 months since NASA picture sets have become available, Sup. Docs. has sold more than	500, 000
and has now printed for sale more than	1, 000, 000

Exhibits

	Amount
In Washington alone during calendar year 1969, exhibit requests totalled	619
Requests during the first 2 months of calendar year 1970 totalled	120
During 1969, NASA was able to fill exhibit requests numbering	683
Exhibits were viewed by	37,600,000
In May 1969, NASA exhibit at the Paris Air Salon drew an audience of approximately	500,000
For Expo '70 at Osaka, the U.S. Pavilion which features a space and lunar rock exhibit is expected to be seen by at least	15,000,000
Requests for displays of lunar samples exceed	1,000

Motion pictures

In calendar year 1969, NASA titles in circulation for general public use was	76
The number of separate prints loaned was	84,231
Audience for these, excluding TV, was estimated at	9,800,000
Apollo films sold through the National Archives have exceeded	1,600
Television stations requested and were furnished prints totaling	7,711
Which were viewed by an audience of	248,500,000
Educational audiences totaled	5,500,000
In showings of NASA films numbering	51,622

Speakers

In calendar year 1969, the number of speeches delivered by NASA personnel to nontechnical groups was	2,049
The audience for these was	265,000
Speech requests received in Washington numbered	529
In 1969, astronaut appearances requests exceeded	5,000
The number of astronaut appearances was	513

Two crews have made round-the-world visits, covering a total of 42 different countries, Guam, and the Canary Islands (some twice).

Visitors

Visitors to NASA facilities in calendar year 1969 numbered over	2,600,000
Of this number, foreigners accounted for about	12,000

Because of public demand, NASA is setting up visitor facilities and programed tours where they have not existed until now, such as Langley Research Center, and to improve or enlarge facilities at other Centers, such as Goddard.

Appendix 6

NEWS MEDIA COVERAGE OF SPACE PROGRAM

The following is a summary of the coverage of the space program by the news media.

Few stories in our history have been so thoroughly, accurately and well covered. Few stories have had the numbers of media representatives following the story and reporting it to the American people—and to people throughout the world.

NASA has conducted a reactive program as far as the news media are concerned. NASA's news services are provided in response to requests, as opposed to traditional publicity or public relations programs: the news media request and we provide answers.

A two-part policy governs the Agency's news operations: (a) release all the information available about NASA and its programs, good and bad, and (b) create a system and a climate wherein media

representatives can come into NASA and its installations to find out for themselves what is going on.

To accommodate media requests and to expedite the flow of information, NASA maintains news operations at each of its installations. During launch periods NASA maintains around-the-clock news operations at Cape Kennedy and Houston's Manned Spacecraft Center and representatives throughout the world where necessary, such as France, Spain, Australia and on recovery vessels.

During launch operations on Apollo 13, as an example, NASA will release television pictures through Canberra, Australia, and Madrid, operate aboard a recovery vessel in the Pacific, allow press pools in Houston's Mission Control and Cape Kennedy's Launch Control and maintain full news operations at key locations. Already there are more than 1,300 newsmen registered to cover this mission.

These statistics will indicate the scope of interest by the news media:

NASA received by mail or telephone in calendar year 1969, 112,643 inquiries for story information, interviews, etc., not including queries during the launch activities.

BONA FIDE NEWS ACCREDITATION FOR APOLLO LAUNCHES

Apollo	Total	Foreign	Foreign countries
7	646	26	11
8	1,500	200	24
9	1,403	63	13
10	1,519	230	25
11	3,497	812	56
12	2,462	388	53

U.S. SPACE PROGRAM AND THE MASS MEDIA

News film—The television networks and local stations received the following footage on these major launches:

	Average footage
Previous manned launches	15,000
Apollo 7	18,000
Apollo 8	21,238
Apollo 9	18,198
Apollo 10	22,186
Apollo 11	34,081
Apollo 12	28,117

STILL PHOTOS

Print Distribution Agency-wide—1969

News photo released	7,575
Prints distributed	1,167,559

NASA also provides four major *feature* services. These services were developed as the result of requests from media asking for *feature* material as opposed to *news* material—and are clearly labeled as such. The requestor receives a service and is periodically taken off the list unless he tells us he desires to continue.

In calendar year 1969, approximately 55% of the feature material related to Apollo, and the rest reported on other aspects of the space program.

It is important to note that the subscriber is told that these materials are not news, but comprise a selection of subjects NASA feels important to disseminate.

TELEVISION

Total U.S. stations on-the-air, 840.

Total subscribers to NASA's Aeronautics and Space Report (monthly, 4½ minutes), 734.

This monthly report, a TV newsreel, is seen in one or more of the top 50 U.S.-TV markets (by number of TV households) covering all 50 States.

Television stations showed (in CY 1969) a total of 7,710 28-minute NASA films covering all aspects of the program. Audience report estimates, 347 million.

RADIO

Total U.S. stations on-the-air, 6,600.

Total subscribers to one or more NASA periodic programs, 3,200.

"The Space Story"—Weekly, 4½ minutes.

"NASA Special Reports"—Monthly, 14½ minutes.

"NASA Space Notes"—Quarterly, 10 1-minute spots.

"Audio News Features"—Premanned launch interviews.

NASA subscribers include at least one station in each of the top 50 radio markets, all 50-States, Puerto Rico, Virgin Islands, Armed Forces Network, Voice of America, and Radio Free Europe.

NEWSPAPERS

Total U.S. English language dailies	1,972
Combined circulation	*61,000,000*
"Space Sheet" subscribers	954
"Space Sheet" circulation	41,600,000

NOTE: "Space Sheet" is a feature page published every other week.

APPENDIX 7

NASA RELIABILITY AND QUALITY ASSURANCE PROGRAM

The NASA Reliability and Quality Assurance (R&QA) program, initiated in 1961, utilizes a combination of management, engineering, inspection and test techniques and disciplines to ensure that aeronautical and space flight hardware will perform successfully. A key element in the realization of this objective is comprehensive, detailed knowledge about the hardware and its operational and performance characteristics. As a result, NASA places strong emphasis on hardware inspection and testing, including comprehensive analysis of anomalies, defects and failures and the development of corrective and preventative techniques. The knowledge gained from these activities has been documented and distributed to other government agencies and industry for use in improving the reliability and quality of other products.

NASA's R&QA knowledge and experience during the past ten years has been documented in over sixty publications which are available through the Government Printing Office or the NASA Scientific and Technical Information Facility. These publications are as follows:

Reliability

1. NPC 250–1: "Reliability Program Provisions for Space System Contractors".
2. NHB 5320.2: "Contractor Reliability Plans and Performance Evaluation Manual".
3. RA 006–013–1A: "Procedures for Failure Mode, Effects and Criticality Analysis (FMEA)".
4. SP–6501: "An Introduction to the Evaluation of Reliability Programs".
5. SP–6502: "Elements of Design Review for Space Systems".
6. SP–6503: "Introduction to the Derivation of Mission Requirements Profiles for Space System Elements".
7. SP–6504: "Failure Reporting and Management Techniques in the Surveyor Program".
8. SP–6505: "Parts and Materials Application Review for Space Systems".
9. SP–6506: "An Introduction to the Assurance of Human Performance in Space Systems".
10. CR–1126: "Reliability Parameter Variation Analysis".
11. CR–1127: "Reliability Computation".
12. CR–1128: "Reliability Testing".
13. CR–1129: "Reliability Prediction".
14. CR–1130: "Parts Reliability".

Quality

15. NPC 200–1A: "Quality Assurance Provisions for Government Agencies".
16. NHB 5300.4(1B): "Quality Program Provisions for Aeronautical and Space System Contractors".
17. NPC 200–3: "Inspection System Provisions for Suppliers of Space Materials, Parts, Components and Services".
18. NHB 5330.7: "Management of Government Quality Assurance Functions for Supplier Operations".
19. RA 001–007–1: "Guide for Preparation of Contractor Quality Plan".
20. RA 001–008–1: "Guide for Preparation of Supplier Inspection Plan".
21. RA 001–009–1A: "Evaluation of Contractor Quality Program Plan".
22. RA 001–010–1A: "Evaluation of Supplier Inspection Plan".
23. NHB 5330.6: "Quality Audit Handbook".

Special Processes, Products, Inspection and Test Techniques

24. NHB 5300.4(3A): "Requirements for Soldered Electrical Connections".
25. SP–5002: "Soldering Electrical Connections—A Handbook".
26. SP–5003: "Selected Welding Techniques—Part I".
27. SP–5009: "Selected Welding Techniques—Part II".
28. SP–5011: "Welding for Electronic Assembly".
29. SP–5013: "Precision Tooling Techniques".
30. TM X–53731: "Mounting of Components to Printed Wiring Boards".
31. TM X–53635: "Investigation of Solder Cracking Problems on Printed circuit Boards".
32. NH B6320.3: "Electromagnetic Compatibility Principles and Practices".
33. SP–5045: "Contamination Control Principles".
34. SP–5076: "Contamination Control Handbook".
35. SP–5074: "Clean Room Technology".
36. NHB 5340.1A: "NASA Standard Procedures for the Microbiological Examination of Space Hardware".
37. NHB 5340.2: "NASA Standards for Clean Rooms and Work Stations for the Microbially Controlled Environment".
38. CR–1110: "Microelectronic Device Data Handbook, Vol. I—Test".
39. CR–1111: "Microelectronic Device Data Handbook, Vol. II—Manufacturer and Specific Device Information".
40. CR–1346: "Application of Monolithic Microcircuits".
41. CR–1347: "Failure Mechanisms of Monolithic Microcircuits".

42. CR-1348: "Failure Analysis of Monolithic Microcircuits".
43. CR-1349: "Reliability Assessment of Monolithic Microcircuits".
44. SP-5031: "Microelectronics in Space Research".
45. SP-5082: "Nondestructive Testing: Trends and Techniques".
46. CR-61204: "Introduction to Nondestructive Testing".
47. CR-61205: "Liquid Penetrant Testing".
48. CR-61206: "Magnetic Particle Testing".
49. CR-61207: "Eddy Current: Basic Principles".
50. CR-61208: "Eddy Current: Equipment, Methods, and Application".
51. CR-61209: "Ultrasonics: Basic Principles".
52. CR-61210: "Ultrasonics: Equipment".
53. CR-61211: "Ultrasonics: Applications".
54. CR-61212: "Origin and Nature of Radiation".
55. CR-61213: "Radiation Safety".
56. CR-61214: "Radiographic Equipment".
57. CR-61215: "Making a Radiograph".
58. CR-61216: "Radiography: Film Handling and Processing".
59. CR-61227: "Classroom Training Manual—Magnetic Particle Testing".
60. CR-61228: "Classroom Training Manual—Ultrasonic Testing".
61. CR-61229: "Classroom Training Manual—Liquid Penetrant Testing".
62. CR-61230: "Classroom Training Manual—Eddy Current Testing".
63. CR-61231: "Classroom Training Manual—Radiographic Testing".
64. SP-9000: "NASA Specifications and Standards".

ABSTRACT AND REVIEW SERVICE

The field of reliability has advanced rapidly since WW II. This has been accompanied by an equally rapid growth of published literature and reports on all aspects of the subject. As a result, the reliability engineer found it nearly impossible to keep abreast of pertinent literature. Recognizing this, NASA, in 1962, initiated a Reliability Abstract and Review (RATR) service to provide a concise, independent, objective appraisal of the quality, significance and applicability of reliability literature pertinent to aeronautical and space activities. This service is performed by the Research Triangle Institute, an independent non-profit research organization, under a NASA contract. From the total sphere of reliability literature, approximately 60 pertinent articles and reports are abstracted and objectively reviewed each month; these are issued by NASA in a monthly publication. The RATR service is available, without charge, to reliability and quality assurance offices of government agencies and government contractors and to academic and industrial libraries having a direct interest in the field. It is also available from the Clearinghouse for Federal Scientific and Technical Information at a nominal fee. There are presently over 1,500 recipients of the RATR service. A typical example is included which was taken from the February 1970 issue of RATR.

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R70-14866 ASQC 810; 863; 871

INTEGRATED LOGISTIC SUPPORT AND ITS IMPLICATIONS FOR RELIABILITY AND MAINTAINABILITY

T. T. Jackson (Booz- Allen Applied Research, Inc., Bethesda, Md.) and A. Luft (U.S. Naval Applied Science Laboratory, Brooklyn, N.Y.) *In: Proceedings of the 1969 Product Assurance Conference and Technical Exhibit, Long Island, June 6-7, 1969* Conference sponsored by the American Society for Quality Control, and the Institute of Electrical and Electronic Engineers New York IEEE, Inc. p 10-16

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An organized approach to the solution of logistic support deficiencies is presented. The approach incorporates the following: timely logistic support planning and funding; an engineering base for support requirements; and integration of logistic support elements in the system acquisition process. There is a continuing relationship between the disciplines of reliability and maintainability and of integrated logistic support which commences early in concept formulation and extends into operation. Integrated logistic support is dependent upon reliability and maintainability inputs for establishment of the basic concept of the logistic support system, for definition of the detailed support element requirements, for feedback and correction of the support system design in accordance with changes in the prime system design, and for evaluation of the support system design. Author

Review. This paper presents a good, brief discussion of the topic indicated in the title The basis for it is DOD Directive 4100.35. The essential features of the relationship between integrated logistic support and the disciplines of reliability and maintainability are clearly presented in an easily-readable form. The paper will be useful to those who are interested in an overview of these relationships. The details of application to any specific system, of course, will have to be worked out.

R70-14860 ASQC 815

MIL-STD-790C—MANUFACTURER'S VIEW

John M. Hammer (Mepco, Inc., Morristown, N.J.) *In: Proceedings of the 1969 Product Assurance Conference and Technical Exhibit, Long Island, June 6 7, 1969* Conference sponsored by the American Society for Quality Control, and the Institute of Electrical and Electronic Engineers New York IEEE, Inc. p 74-78

Details are given on the management planning and organizational structure developed to comply with the quality control and reliability specifications required by MIL-STD-790C. A reliability manual was prepared to cover all facets of the manufacturing operation, and to serve as a guide for all management personnel as well as a practical working program. The responsibilities of the Reliability Committee are defined. The necessary failure analysis equipment is listed, along with the approved test facilities and the steps required for corrective action. Also discussed are the evaluation test procedures, reliability procedure training program, equipment calibration, production processes and controls, documentation, quality assurance inspection programs, audit verification inspection, material traceability system, and distributor quality requirements. M.G.J.

Review: The purpose of this paper and those by Kear and by Wilklow in the same Transactions was to discuss the implementation of MIL-STD-790C. The intent was admirable and the presentations created considerable interest and discussion. The published papers satisfy a need of industry but leave out critical reliability considerations (design details, drawing control, application notes, packaging protection, etc.) and are subject to considerable personal opinion and bias. This paper is a series of *motherhood* statements and an over-simplified overview. It is a manufacturer's interpretation of what should be done to comply with MIL-STD-790C. The author gives the impression that his organization is doing everything required. But does the organization have enough manpower, space, equipment, and research facilities? The paper does not indicate organization size, the number of people engaged in the system described, nor the cost of compliance (perhaps for competitive reasons). The author did not present the philosophy which led to management's decision to install the system to comply "with any military established reliability specification." Without some discussion of the economics involved, one is left wondering why this company does not experience the real-world difficulties which everyone else has. The paper did not discuss the system, required by MIL-STD-790C, to control "Distributor Organizations." (They are treated in the Wilklow paper.) This description of the compliance is more typical of an advertising brochure, a proposal and/or a catalogue preface, than it is a helpful technical paper. It is not recommended reading for other than promotional purposes.

R70-14861 ASQC 813; 815

RELIABILITY ASSURANCE PROGRAM FOR ELECTRONIC PARTS

Donald L. Kear (Defense Electronics Supply Center, Dayton, Ohio) *In: Proceedings of the 1969 Product Assurance Conference and Technical Exhibit, Long Island, June 6-7, 1969* Conference sponsored by the American Society for Quality Control, and the Institute of Electrical and Electronic Engineers New York IEEE, Inc. p 79-87

ALERT PROGRAM

In 1964, NASA recognized the need for rapid dissemination of information relative to problems of general concern in the area of parts and materials, particularly electronic parts. A program was devised known as "ALERT—Reporting of NASA Parts and Materials Problems" for the immediate reporting, on a standard format, and dissemination of such information throughout NASA. ALERT information on parts and materials problems, including the cause and recommended correction action, is also disseminated outside the agency through the Interagency Data Exchange Program (IDEP). On the average, NASA initiates 70 ALERTs annually which are disseminated directly to over 200 government and industrial organizations via IDEP and most of these also distribute the ALERTs to numerous elements within their organization. The value of this NASA initiated information to industry and other government organizations is illustrated by the following examples:

A. Goddard Space Flight Center discovered, through electron beam microscopic examinations of failed microcircuits, that a particular family of microcircuits contained a metallization defect which seriously affected the reliability and performance of these devices in space flight applications. GSFC issued an ALERT in May 1968 which was of immediate value to DoD and the device manufacturer. Microcircuits in this family, from the production lots concerned, were extensively used in both NASA and DoD systems. Thus the ALERT permitted DoD to take prompt corrective and preventative action and also provided the manufacturer with information for improving the manufacturing process to eliminate the defect.

B. Kennedy Space Center, as a result of a flash fire occurring in a commercial resuscitator during checkout testing, discovered, upon dissembly of the resuscitator, that it contained an internal nylon regulator component which was incompatible with oxygen. KSC issued an ALERT in October 1969 and recommended that all users of commercial oxygen resuscitators and other pure oxygen breathing apparatus carefully investigate the components of such equipment to assure that incompatible materials and lubricants are not being used. This ALERT was of particular interest to the U.S. Bureau of Mines and to manufacturers of oxygen resuscitators and pure oxygen breathing equipment. The U.S. Bureau of Mines requested copies of the detailed analysis report from the KSC Materials Analysis Branch and forwarded the report to all Bureau of Mines approved breathing apparatus manufacturers requesting that the manufacturers review their designs and materials and make any changes necessary.

In summary, information pertinent to and resulting from NASA's Reliability and Quality Assurance program has been disseminated and made available to other government agencies, industry and academic institutions on a continuing basis. In addition, the program has been given extensive exposure through NASA Reliability and Quality Assurance participation in professional society symposia and conferences and the publication of professional papers.

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